Weaving a future

for Australia's cotton, catchments and communities

Cotton Catchment Communities CRC

SEVEN YEARS OF COOPERATIVE RESEARCH

An Australian Government Initiative

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I.

David Anthony
Chairman 2005-2012

reflections

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The triumvirate of cotton-based CRCs concludes with the finalisation of the Cotton Catchment Communities CRC (Cotton CRC) in June 2012. Eighteen years of significant investment and collaboration have produced an array of valuable outcomes. Importantly, the dividends from this research and development journey will continue for many years to come for the industry and for the catchments and communities in which it operates.

It is rare that one research organisation or agency has all the skills and resources to successfully address a research issue, but as the chain of cotton-based CRCs has shown, collaboration brings efficiency and commitment across state and agency boundaries.

Key to a CRC is the collaborative effort of its participants and affiliates, who focus on common goals and take into consideration industry priorities. Industries always face short-term challenges that need to be addressed but longer-term success depends on looking beyond the immediate and understanding the contextual and longer-term factors that can have major impacts in time.

The cotton industry has been very fortunate in being awarded three CRCs. Many don't go on beyond the initial term. The success of the first two cotton-based CRCs showed the value that high-performing CRCs can bring.

The Cotton CRC applied in the 9th Round of the CRC Program in July 2004. There were some 87 expressions of interest, of which 14 were successful. A team of ten industry and research people put the case for the CRC to the Department of Education, Science and Training (now the Department of Innovation, Industry Science and Research) in December 2004.

Considerable time was invested in ensuring the goals, intended outcomes and aspirations of the Cotton CRC were precisely what the industry needed but at the same time met the selection criteria set down by the federal government through the then Department of Education, Science and Training (DEST).

In January 2005 we were informed that we had been successful and would receive a DEST cash grant of $26.5 million over seven years. Because we were granted another CRC, one year was taken off the existing CRC, as had occurred for the first cotton-based CRC. The total cash and in-kind budget for the new Cotton CRC was $138 million, though in time more funds were attracted. Some $41.5 million in cash, apart from the DEST grant, was committed at the start.

Considerable credit must go to Guy Roth, CEO, who led the charge for the third Cotton CRC. He had great industry, research organisation and agency support but, nevertheless, pulling a cohesive, focused and technically sound bid together across a myriad of organisations and affiliates takes considerable effort and intellect. Kym Orman, who was Business Manager for the previous cotton-based CRC, ably assisted him in navigating the administrative mazes.

The bid was built around five key programs: The Farm, The Catchment, The Community, The Product and Adoption. In developing the bid, there were a number of factors influencing the work to be done in each of these programs:

- The drying phase in south-east Australia that was causing water supplies to retract was becoming a major issue, putting great pressure on the need for even higher water use efficiencies.
- Natural resource management beyond simply water was becoming a more critical issue, especially vegetation and biodiversity, with the cotton industry seen as an important driver for the uptake of ecosystem services and catchment management activities. As a driver, the Cotton CRC hoped that other agricultural enterprises would learn and adopt from cotton's leadership.
- Transgenic varieties had proved a fundamental and beneficial platform for robust Integrated Pest Management (IPM) systems and, with the widespread use of this technology, it was important that it be well managed and preserved.
- Community issues have always been a critical to cotton, given the importance of regional towns as a source of employees, skills and services. In an increasingly urbanised and coastal nation, finding ways to assist communities in cotton regions to build their capacities and attract people was the subject of a lot of debate.
- Cotton is the largest natural fibre market in the world and has become a major world commodity. While Australia excels in its production, ensuring we remain competitive and continue to attract premium prices was seen as a crucial issue. As well as finding ways to measure the fibre characteristics of Australian cotton to assist spinners, responsible stewardship in production methods through greater use of the industry's Best Management Practice (BMP) program was seen as an important objective to pursue through research and development.

Besides the greater inclusion of catchment research and, particularly, community research, in the Cotton CRC program, this CRC differed from the first two in several ways. Rather than a joint venture of research and industry organisations as the first two cotton-

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based CRCs had been, the Federal Government preferred new CRCs to have a company structure with a competency-based Board made up of a majority of directors independent of the research participants. This created a good deal of administrative work in the beginning, as many of the state agencies were concerned with the tax and potential profit and loss implications a company structure would bring. After considerable dialogue and negotiations, the various teams representing the interests of the participants agreed on a Centre Participant Agreement and adjustments to the Commonwealth agreement were decided. The company, Cotton Catchment Communities CRC Inc., limited by guarantee, was born. Its shareholders were the following Participants:

- The Australian Cotton Growers Research Association Inc. (ACGRA)
- Cotton Australia Ltd
- Cotton Research and Development Corporation (CRDC)
- Cotton Seed Distributors
- CSIRO
- Department of Agriculture Western Australia
- NSW Department of Primary Industries
- Queensland Department of Primary Industries and Fisheries
- The University of New England
- The University of New South Wales
- The University of Sydney
- The University of Technology Sydney

(Note: over the course of the life of the CRC the ACGRA was incorporated into Cotton Australia and some state agencies changed their names).

An eight-person Board was selected, following a call for nominations by the Participants. The Board structure was skills-based, with a majority of independent directors, but also was designed to have three 'college' directors covering, respectively, industry participants, state agency participants and the CSIRO and universities. The original Board consisted of:

- David Anthony (Chairman – Producer, Ginner, Marketer – independent)
- Kathryn Adams (Research, IP – independent)
- Di Bentley (Natural Resources and Agricultural Consultancy – independent)
- John Herbert (Agribusiness, Consulting, CRCs – independent)
- Stuart Higgins (Producer, Communications – independent)
- Bruce Finney (Industry College)
- Helen Scott-Orr (State Departments College)
- Gary Fitt (CSIRO and Universities College)

The new Board began working on CRC matters in April 2005 even though the new CRC didn't commence officially until June 2005. Several Board positions changed over the life of the Cotton CRC, with new Board members Barbara Grey (producer), Rob Dugdale (Industry College) and David Hamilton (State Departments College) replacing Stuart Higgins, Bruce Finney and Helen Scott-Orr, respectively.

The Board has always been a very cohesive group, focused on working closely with the management team to assist in the delivery of outcomes. One of the most notable operational events was Guy Roth's resignation in November 2007. Replacing Guy was always going to be a challenge; however, we were fortunate to hire Phillip Armytage, who had a background in cotton and corporate agro-business industries. It was a seamless changeover.

The 3rd year review was undertaken in October 2008, with a panel led by Dr John Radcliffe and other panel members, Dr Rick Roush and Dr Don Anderson. The Third Year Review was a greatly valuable process, serving as a useful independent audit of the CRC's progress and of the future directions and activities that were to be undertaken. The review outcome was very pleasing for the Cotton CRC Board, highlighting that the CRC was on track and well managed and directed. Many thanks go to the management team, especially the CRC's Chief Scientist, Professor Peter Gregg, and the program managers for the efforts that went into the review.

One of the main recommendations from the review related to the Community Program to ensure it delivered on its intentions. The Community Program presented a number of challenges, due to the social nature of the work required compared to traditional production or environmental research. Many of the concepts were more abstract and thus less easily quantified or measured by traditional means. The lengthening drought and major issues relating to irrigators' access to water gave greater importance to this program and it expanded rapidly in the latter years of the CRC. The Stubbs and Wee Waa drought studies, focusing on water as an important driver of regional communities, were very valuable contributions to our knowledge base, especially in the socio-economic areas. Through the Community Program, the Cotton CRC introduced a series of Sustaining Rural Communities Conferences. Commencing in 2010, these have brought together a wide range of researchers and agencies working on community and social science issues, with the results of work we were undertaking presented for peer review and discussion. The CRC's Chief Operating Officer, Dr Paula Jones, deserves special mention here as it was through her hard work and diligence that the Community Program overcame significant hurdles and flourished in the end.

The Cotton CRC set out to deliver over $1 billion worth of benefits. Since 2005, the industry has faced continuing drought with severely reduced production followed by some significant flooding in the last two years, especially in parts of Queensland. Despite these hurdles we believe we have more than succeeded with our goal of adding $1 billion as a result of the activities of this CRC. While costing social and environmental benefits can be challenging, the gains we have made in these areas, added to the production benefits, including water, IPM and marketing are very substantial and have exceeded our expectations.

It causes a level of disappointment that after 18 years the cotton-based CRCs are coming to an end. The CRC has brought together a talented management team that understands the value of collaboration and inclusiveness in achieving and delivering desired outcomes. The team has honed its skills in project management and science quality. It has employed effective systems to monitor project milestones and keep the Board and program managers abreast of progress.

The loss of research and development investments in agriculture is of significant concern.

The CRC has brought together a talented management team that understands the value of collaboration and inclusiveness in achieving and delivering desired outcomes.

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There is a real danger that market failure will occur in the agricultural research, development and extension (R, D & E) sector if current downward trends in R, D & E funding continues. Much of this sector consists of small and medium-sized enterprises, especially family farms, that don't have the capacity to do extensive research of their own and are broadly spread across the landscape. Adding to this is the fact that you simply can't turn agricultural productivity back on once it has run down below critical levels. It takes time – it's not like making a manufactured part. The CRC program in agriculture has to be built on, as the collaborative investments provide significant benefits to one of Australia's most important and long-term sectors.

> Much of this sector consists of small and medium-sized enterprises, especially family farms, that don't have the capacity to do extensive research of their own.

Many growers have not known a cotton industry without a CRC in place. While the disappointment is understandable, there is also an opportunity for the industry to look at different arrangements and structures to address industry R, D & E challenges. There are many issues requiring work well beyond the current capacity of the industry, which is rebuilding after a decade of drought. The Board and management have been working with a number of industry organisations to develop an Innovation Network, which will incorporate numerous elements of the Cotton CRC program.

The Board and management of the Cotton CRC greatly appreciate the funding received from the various federal governments and their agencies that have presided over the CRC program through the last 18 years. The industry is very thankful for the faith and investment that has been made into this very important and innovative agricultural industry. They have received a great return on their investments.

As the cotton-based CRCs have demonstrated, agricultural industries face increasing complexities. As most farming operations are SMEs, the challenges for modern farmers are immense. Besides the rigors of simply operating and managing a farming operation, a producer has to deal with natural resource management, foreign exchange and marketing activities, policies to do with carbon and climate variability, labour availability and skill levels, transport issues and general business costs. They navigate these challenges without their own HR departments, in-house technical and financial experts or policy advisors.

Before closing, it is appropriate to mention some key people in the industry who had great foresight in encouraging the cotton industry to join the CRC program. Ralph Schulzé who, at the time, was the Executive Director of the CRDC is a visionary who worked very hard to encourage the industry to support a bid for a first CRC and then contributed to a successful application. Dr Greg Constable and Dr Gary Fitt worked very hard for the CRC cause and gave great support to the industry's CRC applications.

On behalf of the Cotton CRC Board I thank the management team, all those involved with project management and leadership, and researchers and extension personnel for their efforts and dedication to the Cotton CRC. The Board is very proud of the respect the Cotton CRC team holds across the industry and in the institutions and agencies that work with our CRC.

II.

Philip Armytage 2008-2012

Dr Guy Roth 2005-2007

reflections

cotton catchment communities crc

The Australian cotton industry has encountered both record droughts and significant flooding since 2005, impacting on its production and profitability. Despite these hurdles, we have achieved our goal of adding $1 billion to the cotton industry through the activities of this CRC. While valuing social and environmental benefits can be challenging, the gains we have made in these areas, added to the production benefits in areas such as water, Integrated Pest Management and processing, are substantial and have far exceeded what we set out to do.

The diversity, length and breadth of the impact of the Cotton CRC's work have shown just how effective a longstanding collaborative research consortium can be. This is the true nature of a CRC. We are a team from multiple organisations, which came together and, with little regard for institutional differences or jurisdictions, worked together to provide significant outcomes that no organisation could have achieved alone.

The Cotton Catchment Communities CRC continued the exceptional work of the two previous CRCs, which had focused on improving production so better crops could be grown more efficiently and sustainably in an ever changing environment. This CRC has built on the improvements the previous CRCs achieved in water use efficiency, in terms of water used per bale of cotton. Improved farming practices, greater information sharing and monitoring of water use have led to substantially improved on-farm water management. These efforts have added in excess of $100 million per year of economic benefit to the industry, all of which is directly attributable to the efforts of those involved in the Cotton CRC.

The Farm Program continued to push boundaries. It has developed the base agronomic information to allow the introduction of cotton production into the tropical sugar farming systems of the Burdekin Irrigation Area in far north Queensland. This new knowledge complements and enhances the tropical cotton production work from the Ord region in North West Australia, which is available as NORpak. The program has also examined and contributed significantly to the knowledge of, and systems for, carbon sequestration, resistance management in insect-tolerant cottons and how to grow cotton rotation crops such as high yielding irrigated wheat profitably.

“An outstanding feature of the Cotton CRC has been the successful integration of the environmental and social programs into the industry framework.”

An outstanding feature of the Cotton CRC has been the successful integration of the environmental and social programs into the industry framework. It is pointless for any agricultural industry to work in isolation from its surrounds, as all are intrinsically connected physically, environmentally and socially to catchments and communities. We continue to discover more and more ways in which our industry is interconnected and reliant on all that is around it.

The CRC has developed groundbreaking collaborative socioeconomic science to understand the fabric of our regional communities. Independent peer-reviewed Cotton CRC work proved critical in the important discussions on the future management of the Murray Darling Basin. This work is still being utilised in the consideration of the development of intelligent policy that will provide certainty for our regional communities in the landscape that comprises agriculture, environment and people.

The establishment of the Sustaining Rural Communities conference has given a voice to remote and regional people, provided a forum for communities to engage and learn from each other and a platform to share social research.

Through our partnership with the Namoi Catchment Management Authority, we have successfully delivered significant environmental on-ground changes, including 120,000 hectares of farming land with property plans, 65 kilometres of riparian areas conserved, 900 hectares of native vegetation conserved and enhanced, and 5,000 megalitres of water saved in the Namoi valley alone.

An especially prominent feature of the CRC has been the integrated and collaborative approach to achieving outcomes across program areas. An excellent example is the inclusion of the landscape-scale knowledge from the Catchment Program into *Pests and Beneficials in Australian Cotton Landscapes,* a crucial industry resource for identifying and managing insects.

Further demonstrations of cross-program integration can be seen in the industry’s myBMP system, where best practices are provided not only for the production of the crop, but also for the management of natural assets, human resources, soil health, ginning, classing, biosecurity and water in the landscape.

reflections

II. Philip Armytage and Guy Roth

The garments produced from Australian cotton are a function of whole of chain actions and management, from agronomic decisions to harvesting operations, ginning and classing processes, spinning and milling activities. The Cotton CRC has built FIBREpak, a resource that includes not just the relevant work of the current CRC but also collates the vast industry repository of information focused on improving the quality and presentation of Australian cotton.

The CRC's success is based not only on the disciplined, rigorous and relevant academic and applied research programs that it manages and monitors but also on the leadership and standing of its scientific teams and the networks created and nurtured to ensure that results are quickly made available and explained to industry.

The Cotton CRC has long recognised that if research is to be truly effective it requires a robust and active process of disseminating information to end users, in order to deliver profitable and effective practice changes. The well-coordinated extension effort of the Development and Delivery team, a unique network of specialists spread across all cotton production regions, underpinned the success of practice change and adaption across the cotton industry. The team has created numerous resources that provided a more commercially orientated yet technically robust process for communicating and assisting the adoption of the results of research.

"The CRC has developed ground-breaking collaborative socioeconomic science to understand the fabric of our regional communities"

It was our aim to establish an ambitious education and training program that supported the growth of postgraduate students, industry, and research and extension personnel. Throughout the life of the CRC we have commissioned and facilitated the successful graduation of 60 PhD, two Masters and 15 Honours students, who have undertaken research across all the program areas. The majority were introduced to the CRC by their participation in our summer scholarships program, or through the completion of their Masters or Honours degrees with the CRC. Through the Cotton Production Course, delivered through The University of New England, the Field to Fabric Course delivered by CSIRO, the Schools Program, scientific exchanges and numerous short courses, our activities have enhanced knowledge and had a significant impact, not only on people in the cotton industry but also our regional communities.

There are many, many other outcomes, such as knowledge and tools for communities to better understand and plan their futures, which are hard to do justice to in this short overview. There are also clever instruments for quantifying the exceptional quality of Australian fibre and science, as well as those that deliver world's best practice for managing pests, water and biosecurity, to identify just a few. This document is an attempt to record and capture some of the astounding collaborative work our CRC has completed. It is by no means exhaustive.

While the Cotton CRC is broadly recognised as a public good CRC, major benefits are also being seen from projects in the diagnostic, insect control, soil moisture monitoring and ginning areas that have a commercial impact. The Cotton CRC and its commercial partners are managing the development and commercialisation of these emerging technologies carefully. Our partner organisations will manage their ongoing development and legacy into the future, on behalf of the industry.

There has been significant disappointment that the Cotton CRC was unsuccessful in gaining an extension to its operations to enable it to address some of the issues which have arisen since its commencement in 2005; however, the industry strongly appreciates the funding it has received over the last 18 years through this and the two previous Cotton CRCs, and the significant difference it has made to our industry, environment and communities. With the prospects of further record plantings and ongoing record investment by our partners in cotton research, it is now timely that the cotton industry takes the collaborative ethos and the relationships established and fostered by the Cotton CRC and evolve to the next model.

> "A great organisation, great people, great achievements and a great history of collaborative research"

There is much to celebrate.

I would like to recognise and thank Board members of the Cotton CRC for their personal support, strategic foresight and the world class capability they have added to the organisation.

I would like to recognise the immense contribution of the management team of the CRC. They are a highly functional and professional team who have made the operations of the CRC seamless through their dedication, patience and deep relationships with our partners. Their commitment has been way beyond just doing their job. Staying as a team right to the end of the CRC to finish what we undertook at the outset demonstrates their loyalty and dedication.

Importantly, I must recognise the researchers who contribute their knowledge, intelligence and willing nature to share, to collaborate. It is these people who create the real means by which to achieve our outcomes. Without them, there would be no CRC.

Above all, thank you and congratulations to those partner organisations that had the vision and commitment to willingly form and resource one of the most imaginative and ultimately highly effective CRCs, even in the face of significant challenges to their own organisations. These organisations have committed to continuing to drive the Cotton CRC work beyond the life of the CRC and to consolidate the strong legacy of the collaboration.

A great organisation, great people, great achievements and a great history of collaborative research will cease to function under the CRC framework as of June 2012, but R&D will continue as just part of the way the cotton industry does its business. I wish them the best of luck in all their future endeavours.

III.


Dr Gary Fitt, CEO 1999-2003


Dr Guy Roth, CEO 2003-2005

reflections
australian cotton crc

With the sound basis of collaboration and industry focus established by the first Cotton CRC – the CRC for Sustainable Cotton Production – the Australian Cotton CRC had a great foundation to launch from. This was meant to be a new CRC so our proposal had to be distinctive, but some of the best elements of the first continued on. As in the first CRC, the CRDC and Cotton Seed Distributors were participants, but further industry engagement came through three companies: Queensland Cotton, Twynam Cotton and Western Agricultural Industries.

Our proposal included five programs. Two of these captured the important production and marketing needs of the existing industry through a Sustainable Farming Systems Program and a Textile Research Program, in which we fully explored the 'field to fabric' pipeline.

As with all CRCs at that time, there was an explicit Education and Technology Transfer Program to ensure training of future researchers and the best possible communication of outcomes to industry and the wider community.

We also added two new programs. The first focused on northern Australia, where we sought to explore options for industry expansion in several regions. In some ways this was a return to the roots of the industry in the Ord river region, where cotton had failed spectacularly in the late 1960s because of insect pests and pesticide resistance. This time we had new transgenic technologies and better farming systems knowledge to help redesign a sustainable northern production system. Other northern research was established in the Katherine region of the Northern Territory and near Richmond in north Queensland.

The second new program was Innovative Technologies, where research with the potential for commercial outcomes was undertaken. Examples included new insect pest attractants, possible diagnostic tools for pathogens and biological control agents. It was a time when CRCs were under more pressure to generate income and, although the bulk of the Australian Cotton CRC research continued to bring benefit through a more productive and sustainable industry, this program captured some valuable Intellectual Property and sought to capitalise on those opportunities.

In the CRC's first Strategic plan we outlined aims to help the industry to:

- attain long term sustainability through responsible management and sensitive development with the environment.
- maintain a position as agricultural industry leaders.
- achieve community recognition as a viable and valuable contributor to Australia's economic and regional development.

reflections

III. Gary Fitt And Guy Roth

HIGHLIGHTS

Northern Australia – NORCott
Our northern Australia research brought the CRC into several challenging interactions, sometimes conflicts, with environmental groups who did not want agricultural development – much less cotton – in that region. We needed to focus on farming systems, public opinion and government policy. The CRC took the lead in completing environmental impact studies for GM cottons in the north, as they would be the basis for any production system. In the end, the research showed that cotton could be grown profitably and with minimal pesticide, and culminated in a comprehensive body of knowledge known as NORCott, which provided a blueprint for growing cotton sustainably in the Kimberley and the Northern Territory. A real innovation was to grow cotton in the dry season and manage the development and maturation of the crop to optimise fibre quality

IPM Short Course
Integrated Pest Management (IPM) had long been a preferred approach to sustainably managing insect pests. While the established Cotton Production Course gave extensive coverage to pest management, it was not targeting growers themselves. One of our excellent initiatives was to introduce an IPM Short Course for growers, which gave them a foundation of understanding with which to more effectively interact with professional consultants in making management decisions.

More coordinated Cotton Extension
This Cotton CRC sought to optimise the transfer of knowledge from research to industry.
A national network of extension specialists across all production regions, overseen by the National Cotton Extension Coordinator, was able to use enhanced forms of communication and training to focus on both local and national extension issues.

Recognition for the Cotton Production Course
A highlight that reflected the key elements of collaboration and end user impact came in December 2000, when the Cotton CRC won the Business/Higher Education Round Table (BHERT) Award for Collaborative Education for our outstanding Cotton Production Course, which represented collaboration among some forty researchers across all the CRC participants.
The Cotton Course commenced in the first CRC, but hit other milestones with the launch of the Cotton Modules CD ROM and a website, designed to facilitate learning through multi-media components. We also saw the emergence of undergraduate modules in cotton production at UNE, The University of Sydney and University of Queensland, Gatton, giving greater exposure to cotton in agricultural training and also increasing the flow of potential PhD students for the industry.

Planning for an Environmental Program
An important initiative that commenced in 2002 was a proposal for a Supplementary Bid for funds to add a 6th program to the CRC.

Titled 'Managing and enhancing agricultural ecosystems', this was to be squarely focused on the environment and issues at the interface with production landscapes. It complemented the establishment of Catchment Management Authorities charged with large-scale management of the environment in response to federal policy. Although the bid was not successful, the thinking and relationships formed led directly into the CRC's next iteration as the Cotton Catchment Communities CRC.

Pressures relating to access to water resources continued to grow during the period of this CRC, particularly in the Murray-Darling Basin, but the cotton industry commitment to Best Management Practices helped to emphasise gains in water use efficiency, reduced reliance on pesticides through *Bt* cottons, continued improvements in soil management and overall enhanced environmental credentials. The Cotton CRC was pivotal in contributing sound research in all these areas.

The BDA group undertook an independent economic evaluation of the Australian CRC research outcomes and identified that it had delivered over $568 million of benefit to the Australian cotton industry.

The Australian CRC and its predecessor, the CRC for Sustainable Cotton Production, built a high level of trust and respect within the Australian cotton industry through its dedication, hard work and ingenuity of many dozens of researchers over the years.

IV.

Dr Greg Constable 1994-1999

reflections

crc for sustainable cotton production

The Federal Government's CRC Program was established in 1990 to 'match the technology push provided by [Australia's] strong research base with the demand pull of industry and other research users'. The CRC Program was established primarily as an industrial research program that supported industry and business development across a broad range of sectors, including agriculture, fishing and forestry, information and communications, mining, manufacturing, energy, health care, water services, transport and construction. A primary objective was to obtain synergies by bringing R&D and industry together. The first 15 CRCs were announced in March 1991.

Preparations for an application to establish the CRC for Sustainable Cotton Production began in mid-1993. There was good industry involvement, with NSW Agriculture, now the Department of Primary industries (DPI), Queensland DPI, now the Department of Employment, Economic Development and Innovation (DAFF Queensland), CSIRO, the University of New England (UNE) and Sydney University all making strong contributions to the planning committee. The case was around 'development and delivery of collaborative scientific and education programs to promote a sustainable Australian cotton industry with benefits that flow to the community'. There was a drought at the time and limitations on CRDC funds were a further incentive for attracting funds for a new CRC. The cotton industry had grown rapidly during the 1980s with little increase in research numbers, so a new CRC was an opportunity to build research and extension capability.

A detailed case prepared by the planning committee involved four programs:

1. Sustainable management of the **resource** base;
2. Environmentally responsible **crop protection** practices;
3. **Breeding** commercial cotton varieties adapted to Australian conditions; and
4. Promoting awareness and **adoption** of new technologies to growers, consultants and community.

Education and training were spread across the programs and a farming systems project was also soon overlaid to ensure integration of the scientific outcomes.

The application was submitted in late 1993 and we were granted an interview. We decided to have two practice interviews in preparation – these were ten times tougher than the real thing, as our practice panels were tigerish in grilling the team. This process would have sapped the confidence of John McEnroe. The real interview was approached with great trepidation, as public and government perceptions of the cotton industry were strongly negative on water and pesticide issues. However, we had a strong case and were successful for a seven year non-incorporated CRC to start in July 1994.

The CRC for Sustainable Cotton Production began operations with NSW Agriculture as Centre Agent, later replaced by CSIRO. The CRC was initially lean and mean in overheads: only one administration position was funded by the CRC, with the rest in-kind from research providers. A number of key projects were immediately put in place and the R&D portfolio grew over the next year. Additional administration staff were added in later years, as managing and reporting demands outstripped the capacity of the 'in-kind' contributions.

There were numerous challenges in the early years – we hadn't done this before, so the goodwill that is now taken for granted as part of the Cotton CRC model had to be forged between organisations and individuals. There was also a fine line between having a broad range of research subjects, which could lead to a lack of focus, compared with fewer, deeper projects with a narrower focus. In the end, we elected to specialise in sustainability issues. Breeding dropped from under the CRC umbrella in 1998. CRDC's direct involvement in this first CRC was much less than with the current CRC. Even by 1998, only one project was directly funded by CRDC, with all other CRC projects funded from CRC funds. To address the aim of developing a larger research base, smaller research providers actually received a proportionally larger share of CRC funds.

The transition from the CRC as a research funder to an R&D coordinator, as it is now, also evolved through time. Many CRCs at this time had been established with the intent that they would eventually generate income and be independent. The CRC for Sustainable Cotton Production was never intended to go that way: our R&D was in environmental and public good matters, rather than commercial, as a more profitable cotton industry with healthy resources would have greater positive impacts in rural communities than developing products to sell to industry.

In terms of management, the CRC Board had three positions in common with CRDC. This was not desirable and did not encourage independence and distinction for the CRC. In contrast, a majority of the CRC Management committee was research providers and worked very well. This team felt ownership of, and responsibility for, CRC activities and applied rigour in the development, application and delivery of projects.

reflections

IV. Greg Constable

HIGHLIGHTS

All projects in the CRC for Sustainable Cotton Production were undertaken with great care and commitment. The CRC initiated and delivered some key research projects. A good example is the research to develop *Bt* resistance management strategies. Ingard® (single gene Bt) cotton was due for release in 1996 and experience with pesticides was that *Helicoverpa armigera* was likely to develop resistance to *Bt* unless a preemptive strategy was put in place. A strategy was developed, promoted and delivered and the core elements are still in place for Bollgard II® in 2012. A commissioned economic assessment by the Rural R&D Corporations in 2009 showed this and subsequent cotton *Bt* resistance management projects would have a net present value of over $300m after ten years if resistance was prevented.

Other achievements in the first Cotton CRC were:

- In resources, soils in cotton regions were mapped for physical and chemical properties and increased attention was paid to whole farm water balance;
- In crop protection, more research was undertaken on emerging pests; the original research by UNE which led to the development and subsequent commercialisation of Magnet® was started and research on Fusarium wilt was increased substantially.
- In breeding, there was increased collaboration between biotechnology and breeding; discoveries were made on sources of resistance to Fusarium wilt and introgression of bacterial blight resistance into Pima cotton was achieved.
- The concept of integrating research elements into farming systems was introduced.
- The Technology Resource Centre was established to develop and distribute all research and extension written and computerised products. A CRC website was established and to this day supplies a wide range of information and services. Extension was more formally organised into teams and Industry Development Officers were appointed to some regions. A National Cotton Extension Coordinator was appointed to coordinate the five extension focus teams.
- The Certificate and Postgraduate Certificate in Rural Science (Cotton Production) were introduced at UNE and have been spectacularly successful in training many people who have stayed in the cotton industry.
- Many postgraduate and post doctoral projects were put in place during the first Cotton CRC. Some of those people are still in the industry and making substantial contributions to science and to the cotton industry. Others have moved elsewhere but took with them expert knowledge of cotton, which helps awareness in the wider community of the cotton industry's challenges.

A further highlight of the first Cotton CRC was further building a tradition of collaboration between research providers to undertake high-standard R&D on important industry issues. This is an important concept that requires much work and commitment but pays large dividends when successful. The experience and lessons from this CRC were applied in developing the case for an Australian Cotton CRC to begin in 2000.

V.

a cotton industry second to none

The modern Australian cotton industry was established in the 1960s by a small group of pioneers. From these modest beginnings, some 50 years later, it is the third largest agricultural export industry in Australia and stretches from Emerald in Central Queensland to Griffith in Southern NSW, with small plantings further north in the Burdekin Region and the Ord River area in Western Australia.

Cotton is the most commonly produced natural fibre in the world. Every day, Australians wear cotton clothing and use cotton seed products. Cotton seed is a major source of protein for livestock industries, while its oil is an important domestic and industrial product.

The Australian cotton industry is one of the nation's biggest rural export earners contributing around $2.5 billion to the Australian economy and is vital for the prosperity of many regional communities. For each of the last 20 years, Australian growers have achieved the highest yields of all major cotton producing countries, about double the world average. The fibre quality of Australian cotton is among the best in the world for the main upland varieties and it is prized by international spinners for blending with lesser growths to produce fine cotton yarn.

Throughout the nine cotton growing catchment areas, 1,500 cotton enterprises grow some of the finest cotton in the world. The cotton industry has brought considerable prosperity to the communities in which it has grown and employs about 10,000 people directly in regional areas. Today's cotton farms are typically 500 to 2000 hectares, highly mechanised, capital intensive, technologically sophisticated and require high levels of management expertise.

Cotton farms are generally mixed operations, also producing other agricultural products such as grain, oilseeds, beef and wool. The Australian cotton industry leads farming innovation and provides a model of efficiency within Australian agriculture and food production. Cotton was the first industry to widely adopt precision farming, transgenic traits and a formal best management practices system, which are now benefiting many other agricultural industries.

Despite a decade of drought which only relinquished its hold in the 2009–10 season, the Australian cotton industry has achieved a 126 per cent increase in production, while the area devoted to cotton has increased by only 50 per cent. The resilience of the industry is indicated by the rebound from the lowest production in modern times to the highest, in only three seasons. Together with its high gross margins relative to other broad acre irrigated crops, this makes cotton ideally suited to irrigated agriculture in regions of variable water availability, such as the Murray-Darling Basin.

The Australian cotton industry is well known for its innovative approach to production, which has resulted in the industry being world leaders in terms of yields, quality, production costs per kilogram, and being among the most ecologically sustainable cotton produced anywhere in the world. These outstanding results have been achieved through:

- A high and sustained investment in research;
- Industry wide input to research direction;
- An open, sharing culture leading to fast adoption of best practices as they evolve;
- High level of cotton specific training of personnel; and,
- Australia's open market maintaining our competitiveness.

COTTON GROWING AREAS: The Australian cotton industry stretches from Emerald in Central Queensland to Griffith in Southern NSW.

The cotton boll growth phase.

VI.

the crc program

The Commonwealth Government initiated the Cooperative Research Centres (CRC) program in 1991 to *'deliver significant economic, environmental and social benefits to Australia by supporting end-user driven research partnerships between publicly funded researchers and end-users to address clearly articulated, major challenges that require medium to long term collaborative efforts.'*

To date, the Australian Government has funded 190 CRCs. The Australian Cotton Industry has been fortunate enough to secure funding for three CRCs in the form of the:

- Sustainable Cotton Production CRC 1994-1999
- Australian CRC 1999-2005
- Cotton Catchment Communities CRC 2005-2012

Importantly, the key reasons for the success of the three Cotton CRCs have been their strong end-user focus ably supported by long-term commitments from the partners and affiliated organisations.

Erin Richmond & Mark Johnson
Cotton CRC DIISR representatives.

VII.

the cotton catchment communities crc

The Cotton Catchment Communities CRC

The Cotton Catchment Communities Cooperative Research Centre (Cotton CRC) aims to provide high quality collaborative research, education and adoption activities which benefit the Australian cotton industry, cotton catchments and regional communities.

The Cotton CRC has been based at the Australian Cotton Research Institute, Narrabri, NSW and brought together 11 core participants and over 30 affiliate organisations including commercial companies, industry bodies, research organisations, universities, state agencies, catchment bodies and community groups. This mix of organisations enabled the Cotton CRC to develop, fund and manage over 400 collaborative projects addressing a range of issues relevant to the industry, its catchments and communities.

VII. the cotton catchment communities crc

At the time of the Cotton CRCs establishment in 2005 there were a number of factors influencing the research that was needed:

- Water supplies were becoming scarce, as the drying phase in south-east Australia continued. This was becoming a major issue, putting increased pressure on the industry for even higher water use efficiencies.
- Transgenic cotton varieties continued to change the face of farming. With the emergence of new pests and the question of insect resistance associated with the widespread use of transgenic cotton technology, it was vital that this technology be well managed and preserved.
- Natural resource management was becoming a more critical issue, especially vegetation management and biodiversity. Many cotton farms are located along the riparian zones and floodplains of inland catchments and there was an opportunity for the cotton industry increase its contribution to the overall health and management of these catchments.
- Rural communities have always been a critical to a vibrant productive cotton industry. These communities provide the wider services to the industry such as employees, health, education and business. Finding ways to assist communities in cotton regions to build their capacity and flourish was important given the diversity of challenges that rural communities face.
- While Australia excels in its cotton production, ensuring we remain competitive and continue to attract premium prices was seen as a crucial issue.

As a result the research and development activities of the Cotton Catchment Communities CRC were conducted within four research program areas: The Farm, The Catchment, The Community and The Product. These core research areas were underpinned by a strong Adoption as well as an Education & Training which aimed to increased the adoption of new knowledge and enhance the decision making capability of people working in or with the cotton industry, its catchments and communities.

Key outcomes have been:

- internationally competitive cotton farming systems;
- best practice cotton enterprises delivering sustainable ecosystems and reduced impacts on catchments;
- mutually beneficial interactions between industry and regional communities;
- high quality consumer preferred cotton;
- increased adoption of new knowledge and enhanced decision making capability of people working in or with the cotton industry, its catchments and communities.

What makes this Cotton CRC unique is being among the few CRCs that have had their headquarters and focus in regional Australia, central to the industry they serve. This has enabled the CRC to directly contribute to the sustainability of the cotton industry and the catchments and communities it is located within. Like all good things, it must come to an end. The Cotton CRC formally closes on the 30th June 2012 leaving behind an important collaborative legacy for the industry and its regions.

VIII.

managing cooperative research

Over the life of the Cotton Catchment Communities CRC, we have successfully managed 428 research and extension projects, involving over 1000 people and ranging from Geelong in the south to the Ord in the west and Ayr in the north.

Successful in winning another round of funding support for a cotton industry CRC from the Australian Government through the Department of Education, Science and Technology (DEST), now the Department of Innovation, Industry, Science and Research (DIISR), the CRC partners set about establishing the new Cotton Catchment Communities CRC in 2005.

The new CRC was fortunate in that many people and organisations involved had been active in the previous two cotton-based CRCs, the CRC for Sustainable Cotton Production and the Australian Cotton CRC, and therefore had a good understanding of the CRC program and the way in which it operates. This made the transition to the new Cotton Catchment Communities CRC (Cotton CRC) a relatively smooth process.

Following the announcement that the proposed Cotton Catchment Communities CRC was successful, Participant representatives appointed the independent members of the Board in March 2005 following a selection process. The three Participant college directors were appointed later in 2005 and covered the three colleges of CSIRO and Universities, State Government Agencies and cotton industry bodies, including the CRDC, Cotton Australia, ACGRA and CSD.

Core to the success of a CRC is a diligent and engaged Board of Directors and management team to implement

strong corporate governance. Some of the first actions of the Board were to confirm the appointment of a CEO and Business Manager and establish two Board sub-committees (Audit and Human Resources) and three research panels (Science, Adoption, and Catchment and Communities) to enhance governance arrangements and provide advice on the development of Cotton CRC programs and projects.

Under the CRC program guidelines of the time, the Cotton Catchment Communities CRC became an incorporated company limited by guarantee on 20 September 2005 and began formal operation on 1 October 2005. For the Board, staff members and Participants, an incorporated company was a new way of operating a CRC, as the two previous cotton industry CRCs had operated as unincorporated joint ventures, with the CSIRO acting as the Centre Agent

The Board became active prior to July 1, 2005 but there was a delay in the formal operations of the Cotton CRC (which started 1 October 2005 rather than 1 July 2005), largely due to the time it took to terminate the previous Australian Cotton CRC contract, assign projects from that CRC to the new Cotton CRC, finalise the details of the Participants Agreement with all Participants and transition the operations of the CRC from an unincorporated joint venture to an incorporated company limited by guarantee

One of the most significant challenges was setting up new processes and structures that operated as a company required. This meant ensuring that the Cotton CRC governance was compliant with the Corporations Act 2001 and also that it was continually able to meet the ASX 'Principles of good corporate governance and good practice recommendations' (Corporate Governance Council, November 2006). Many of the governance guidelines and templates provided by DEST at the time were extremely useful in providing a starting point for setting up the company governance arrangements.

Management Structure

The size and research scope of the new Cotton CRC required a level of program and project management that was more extensive than the previous two CRCs.

The management structure has essentially remained the same over the past seven years, with the exception of the new part time position of Chief Operating Officer created in January 2011. This coincided with the partial retirement of the Chief Scientist and was established to focus more specifically on the achievement of the Cotton CRC outcomes. The Chief Scientist continued to remain focused on ensuring science excellence and on the PhD program.

VIII. managing cooperative research

The Cotton CRC Board

The role of the Governing Board was to set policy and provide strategic direction to the Cotton CRC in line with the commitments and objectives of the case for the CRC that had been put to DEST. As well, the Board's role involved acting in the best interests of the Company (the Cotton Catchment Communities CRC Limited) and monitoring overall performance to achieve the outcomes that were expected. The Board was cohesive, responsive and highly functional and the respect between the Board and management made for a very purposeful and professional organisation. This can be largely attributed to the appointment of Board members with a strong commitment to the industry, selected for a broad range of expertise that included research and development management, commercialisation and Intellectual Property (IP) management, education and training, finance and business management, cotton production, cotton marketing, natural resource management and corporate governance.

Several Board performance evaluations and reviews were undertaken over the life of the CRC and were very useful in ensuring the focus, cooperation and functionality of the Board were maintained with openness and professionalism.

Cotton CRC Company Management Team

The Company Management Team (CMT) was established in June 2005, to support and advise the Board on operational issues relating to research, commercialisation, communication, and education and training. The CMT met monthly, led by the CEO. It also comprised the Chief Operating Officer (COO), Chief Scientist, Business Manager, Project Management Officer, Accountant, Program Leaders and Communications Manager. The key roles of the CMT were to review and provide recommendations on new research projects, monitor and flag potential issues within projects, facilitate and coordinate the delivery of project and program outputs, and provide program updates to the Board.

> 'The Cotton Catchment Communities CRC is a well structured and effectively managed CRC with a generally sound program structure. It is making good progress.'
>
> **Peter Johnson,**
> **Chair CRC** Program, DIISR

One of the most effective tools for managing Cotton CRC projects proved to be the Red Amber Green (RAG) report completed each month by the Business Manager/Accountant, Project Management Officer and Program Leaders against every current project. This provided the CMT with a full financial, contractual and scientific picture of the project and allowed each problem to be flagged and dealt with early, before it became a significant issue. The performance of the CMT was extremely effective and was one of the key mechanisms that enabled the Cotton CRC to manage and achieve its outcomes successfully.

Centre Forum

The Board received strategic input and advice from the Centre Forum, which comprised all partners and associated affiliates. This proved a very important activity for communication and dialogue on key aspects of the Cotton CRC's progress, activities, commercialisation and other key issues identified by the members, partners and Board.

Evaluating the performance of the Cotton CRC

The Cotton CRC participated in one independent review, which fulfilled the CRC Program's requirement for a third year independent review. This review was undertaken in October 2008 by a panel consisting of a DIISR representative and two independent reviewers with expertise in agriculture research.

Overall, the panel found that the Cotton CRC was performing well. They provided useful suggestions to improve some areas of research development and project management and reporting, which were implemented by the Board and CMT.

"*...the Cotton Catchment Communities CRC is a well structured and effectively managed CRC with a generally sound program structure. It is making good progress.*"
Peter Johnson, Chair CRC Program, DIISR

Strategic Reviews

For the first five years of the Cotton CRC, the Board, along with key stakeholders, program leaders and end-users, undertook a review of the Cotton CRC strategic plan and its programs.

This was a particularly important process, especially given the continuation of the drought and its impacts on some of the proposed activities, which couldn't be undertaken due to the lack of water and the constriction of the industry. It also provided some clear direction for the requested revision of the Cotton CRC Commonwealth Agreement in 2011.

Early in the Cotton CRC, discipline reviews were undertaken in various research fields to gain a better sense of the type and diversity of the work being undertaken and to create an occasion whereby researchers in the same field could exchange ideas and share their results. These reviews played an important role in providing the Cotton CRC and research partners with an assessment as to where science gaps still existed and also of the requirements of end-users. They also proved to be a great incubator for new collaborative project ideas, which were later supported by the Cotton CRC and its partners.

Strong governance has been a hallmark of this Cotton CRC, largely due to the way in which the Board, Staff and CMT worked together to develop and follow all established policies and procedures. Key to this has been regular reporting to the Board and CMT, close adherence both to our policies, as outlined in the Corporate Governance Manual, and to our financial and project control processes, as outlined in the Procedures Manual.

The Cotton CRC undertook various governance reviews, including financial management by the Cotton CRC Audit Committee, an annual external Financial Audit by Nexia Court and Co, identification and review of OH&S procedures, CMT project reporting and an annual Risk Assessment and Fraud review to identify, assess, monitor and manage risk. These reviews safeguarded the integrity of all financial reporting and governance of the Cotton CRC over its life.

To coincide with the transitioning of the Cotton CRC Extension Team to the new and more target-orientated Development and Delivery Team in 2008, the Cotton CRC developed a new Monitoring and Evaluation (M&E) framework. This framework was aligned with the new recommendations to DIISR at the time to use a logic approach to CRC Monitoring and Evaluation (M&E).
As part of its development, the Cotton CRC was able to state clear targets for adoption, align its subsequent end-user surveys to collect the right type of data to demonstrate research usage, create a clear focus for the Delivery Team to prioritise its extension activities and report progress against the Commonwealth Agreement to the Board and DIISR.

IX. our partners

In 2005, the Cotton CRC had twelve core Participants and 34 affiliate partners. These Participants gave the Cotton CRC a local, as well as national focus across the broad range of research fields. In 2008, the Australian Cotton Grower Research Association (one of the Cotton CRC's core Participants) merged with Cotton Australia (another core Participant), reducing the final number of Participants in the Cotton CRC to eleven.

The Cotton CRC Participants and key affiliates, which represent R&D providers, industry, universities, catchment and community organisations, have all committed significant funding, resources and research expertise to the Cotton CRC's research, education and extension agenda.

Cotton Australia

COTTON AUSTRALIA

Cotton Australia is the peak body for Australia's cotton growing industry, servicing growers in NSW and Queensland. Cotton Australia is a legislated representative organisation in the cotton industry to the Cotton Research and Development Corporation (CRDC). In this role, Cotton Australia advises both the Cotton CRC and CRDC on cotton grower priorities in research, development and extension areas, and lobbies research issues on behalf of cotton growers.

The Cotton CRC has worked closely with Cotton Australia to develop and implement the industry's Best Management Practices (BMP) program, which is industry's commitment to the world's best practice in cotton production. Over the life of the Cotton CRC, Cotton Australia has been involved with 60 research and extension projects.

CRDC

Australian Government
Cotton Research and Development Corporation

The Cotton Research and Development Corporation (CRDC) is a partnership between the Australian cotton industry and the Australian people, through the Australian Government. CRDC invests in research, development and adoption that leads to increased productivity, competitiveness and environmental sustainability to benefit the Australian cotton industry and wider community. CRDC is a significant investor in, and the largest commercial partner of, the Cotton CRC, investing in 150 projects across all programs.

Cotton Seed Distributors

CSD

Cotton Seed Distributors (CSD) is the industry's largest supplier of cotton planting seed, from varieties improved and bred in Australia. CSD works closely with the CSIRO Division of Plant Industry to have available the best possible varietal performance in conventional material and the transgenic market, combining the attributes of the conventional varieties with the best possible biotechnology performance.

CSIRO

CSIRO, the Commonwealth Scientific and Industrial Research Organisation, is Australia's national science agency. CSIRO has brought expertise and infrastructure through its Sustainable Agriculture Flagship, Plant Industry (PI), Entomology, Materials Science and Engineering (MSE), Land & Water, Sustainable Ecosystems and Ecosystem Sciences divisions. CSIRO researchers have been involved in 105 research projects across all research programs of the Cotton CRC

The University of Sydney

The University of Sydney, founded in 1850, has an international reputation for outstanding teaching and research excellence. The Cotton CRC has worked closely with the Faculty of Agriculture through 53 collaborative projects including 16 PhD students.

The University of New England

The University of New England (UNE) is one of Australia's leading regional universities, and a major provider of distance education, serving over 17,000 students globally. Based in Armidale, NSW, UNE is the closest university to the major cotton growing regions. UNE researchers and students have been involved in 57 research projects across all research programs including 20 PhD students. The Cotton CRC Cotton Production Course is facilitated by UNE.

University of New South Wales

The University of New South Wales was established in 1949, and has expanded rapidly and now has close to 40,000 students. The University offers more than 300 undergraduate and 600 postgraduate programs. The Cotton CRC works with the School of Biological, Earth and Environmental science and the UNSW Water Research Laboratory. UNSW researchers have been involved in 11 projects with the Cotton CRC, primarily in the Catchment Program.

University of Technology Sydney

The University of Technology (UTS) is a dynamic and cosmopolitan university that marks the gateway to Sydney. The Cotton CRC has been engaged in six research projects with UTS, primarily in the Catchment Program.

IX. our partners

NSW DPI

The NSW Department of Primary Industries acts in partnership with industry and other public sector organisations to foster profitable and sustainable development of primary industries in New South Wales. With a staff of 3500 based at over 130 locations across the state, the department delivers a wide range of services to primary industries and rural communities. The partnership between the Cotton CRC and NSW DPI is crucial as it provides the support needed to extend research and promote adoption within the Australian cotton industry. The Cotton CRC is headquartered at the Australian Cotton Research Institute at Myall Vale, near Narrabri, which is operated by NSW DPI. Over the life of the Cotton CRC, NSW DPI has been involved in 55 research and adoption projects.

DAFF Queensland

The Department of Agriculture, Fisheries and Forestry (DAFF Queensland) includes the former Department of Primary Industries and Fisheries. It promotes profitable primary industries for Queensland by providing expertise and support to assist the State's food and fibre industries to increase productivity, improve sustainability, grow markets and adapt to change. The partnership with the Cotton CRC has been crucial, as it provided the support needed to extend research and promote adoption within the Australian cotton industry. Staff from DAFF Queenslandinvolved in 50 research projects the Cotton CRC, in the Farm and the Adoption Programs.

Western Australian Department of Agriculture and Food

The Western Australia Department of Agriculture and Food (WA DAF) assists the Western Australian agriculture, food and fibre sectors to be sustainable and profitable, with a clear focus on export-led growth. The Department enhances the international competitiveness of the State's agribusiness by working with them to meet the increasingly demanding standards for safety and quality of food and fibre products produced in a sustainable way. Over the past 7 years the Cotton CRC has conducted 7 projects with staff of WA DAF, centred on the Ord River region of Western Australia.

affiliates

These tables list the Participants and key affiliates and their respective cash and in-kind contributions over the last 7 years. Through these cash and in-kind contributions, they have enhanced the Cotton CRC's ability to deliver outcomes to a wide range of end-users across Australia.

Aboriginal Employment Strategy Ltd

AgBiTech

Aquaculture Association Qld

Aquatech Consulting Pty Ltd,

Australian Cotton Shippers Association

Australian Cotton Trade Show

Boyce Chartered Accountants

Central Queensland University

Charles Sturt University

Condamine Alliance

Conservation Farmers Inc

Crop Consultants Australia

Department of Environment and Resource Management

Dunavant Enterprises Pty Ltd

Grains Research and Development Corporation

Greening Australia

Greenmount Press

Growth Agriculture Pty Ltd.

Incitec Pivot Ltd

Inverell Shire Council

Millmerran Shire Council

Monsanto Australia

Namoi CMA

Narrabri Shire Council

Narromine Shire Council

NSW Office of Water

Orica Ltd

Queensland Cotton

Queensland Murray Darling Committee

Sunwater

The Australian National University

The Courier Group

The University of Queensland

Warren Shire Council

x. company board

Mr David Anthony Chair B.Sc. Agr. GAICD (2005-2012)

David Anthony has 35 years background of science in agriculture. In the past, he was Vice Chairman of the Australian Cotton Growers Research Association for 15 years, Treasurer of Cotton Seed Distributors Limited for nine years, a Director of Cargill Oilseeds Australia and Cargill Processing Limited for eleven years and Director/ Vice Chairman of the Cotton Research and Development Corporation for nine years. He has been a Director of the Australian Farm Institute since 2008 and was a member of two NSW State Government Primary Industries Councils from 2005 to 2011. Currently, David is the CEO of Auscott Limited and Chairman of the Cotton Catchment Communities CRC since its inception. He is a member of the Cotton CRC Human Resources Committee.

Mr John Herbert (Deputy Chair) (2005-2012)

FAICD FAIM

John Herbert has had a lifetime experience in agribusiness at CEO and Director level. This has included significant experience in research management and commercialisation in the private and public sectors. He has a strong interest in and a practical approach to effective corporate governance. John has served on the Board of RIRDC and Golden Casket Lottery Corporation and as Chair of the Rice CRC and the CRC for Tropical Plant Protection. In addition to his role on the Cotton CRC Board he is Chair of the Right Mind Pty Ltd. He is Chairperson of the Cotton CRC Human Resources Sub-Committee.

Dr Gary Fitt (2005-2012)

BSc (Hons), PhD, ATSE, GAICD, FRES

Dr Gary Fitt has extensive experience in the science of agricultural systems and sustainability. Prior to his current appointment as Deputy Chief and Senior Principal Research Scientist, CSIRO Ecosystem Sciences, he was Deputy Chief and Strategy Director, CSIRO Entomology, Chief Executive Officer for the Australian Cotton CRC and before that a Program Leader Cotton CSIRO Plant Industry. Gary is Chair of the Science Advisory Body for the OECD Cooperative Research program on Sustainable Agriculture, an elected Fellow of the Academy of Technological Sciences and Engineering, a fellow of the Royal Entomological Society of London, and member of the Australian Entomological Society and British Ecological Society. Gary is Chairperson of the Cotton CRC Science and Education Specialist Advisory Panel.

Ms Kathryn Adams (2005-2012)

B.Sc. Agr (Hons), M.Env Stud, M.Bus, LLM, FAICD

Kathryn Adams has extensive experience in agricultural science, agribusiness and intellectual property law. She is an adjunct Senior Research Fellow with the Australian Centre for Intellectual Property in Agriculture at Griffith University. She has served on the boards of several Cooperative Research Centres and Research and Development Corporations (including the Cotton Research and Development Corporation), and has held a range of senior executive positions. Kathryn's expertise encompasses intellectual property, corporate governance, R&D investment, business development and environmental management. She is Chairperson of the Finance and Audit Committee.

Mr W. David Hamilton (2009-2012)

B Agr Sc (Queensland), MS (Agron) (Texas A&M), FAICD

David Hamilton has extensive experience and interest in field crop agriculture and in the application of technology. He has particular interests in research, development, extension and education, especially in the cotton industry, having previously served on the Cotton Research and Development Corporation Board. He is the elected Board representative of Queensland Department of Primary Industries and Fisheries, the NSW Department of Primary Industries and WA Department of Agriculture. David is a member of the Finance and Audit Committee.

Ms Diane Bentley (2005-2012)

B. Sc. Agr., GAICD

Diane Bentley has extensive expertise and interest in sustainability issues in relation to agriculture and natural resource management, policy development and research and development investment. She is Assistant Commissioner of the Natural Resources Commission of NSW, a Director of Land and Water Australia, Deputy Chair of the Grains Research and Development Corporation Northern Panel and a Member of the CB Alexander Foundation. Diane is Chair of the Cotton CRC Catchment and Communities Specialist Advisory Panel and a member of the Human Resources Sub-Committee.

x. company board

Ms Barbara Grey (2009-2012)

Adv.DipBus, GAICD

Barb Grey is an irrigation cotton farmer from Mungindi, south west Qld. Barb has a particular interest in human resource management, and currently sits on the Cotton Australia Human Capacity Panel. She is the former Chair of Wincott, a graduate of the Australian Rural Leadership Program, and the 2011 recipient of the RIRDC Rural Woman of the Year - Qld & National Runner-up. Barb is a member of the Human Resources Committee.

Mr Robert Dugdale (2009-2012)

DipApSci(Ag), GAICD

Robert Dugdale has 30 years experience in Research, Sales, Marketing and Management within companies such as Shell Australia Limited and AgrEvo Limited. Currently the CEO of Cotton Growers Services Limited, a member of the Australian Cotton Industry Council and The Cotton Agricultural Products Association. Formerly a Director of Cotton Communications Limited. Special interests include marketing, commercialisation and strategy implementation. Rob is a member of the Cotton CRC Audit Committee.

past board members

Ms Helen Scott-Orr (2005-2008)

BVSc (Hons), Dip.Bact. (Lond.), MACVS (Epidem.), FAICD

Helen Scott-Orr has extensive experience and interest in agriculture and veterinary research, policy, extension and education, especially relating to biosecurity and sustainability, as well as corporate governance of CRCs and similar alliances. Helen was the elected Board representative of the Queensland Department of Primary Industries and Fisheries, NSW Department of Primary Industries and WA Department of Agriculture, and a member of the Cotton CRC Finance and Audit Sub-Committee.

Mr Bruce Finney (2005-2008)

BSc Ag, GAICD

Bruce Finney has extensive experience in the agricultural sector. Prior to his appointment as Executive Director of the Cotton Research and Development Corporation he worked for Twynam Agricultural Group in various roles, including Company Agronomist, Regional Manager of the Central Region and Natural Resource Management Coordinator. He is a past Chair of the Australian Cotton Growers Research Association and a graduate of the Australian Rural Leadership Program. Prior to his resignation, Bruce was an elected Board representative of the Cotton Research and Development Corporation, Cotton Seed Distributors Ltd, Cotton Australia Limited and the Australian Cotton Growers Research Association Inc. He was a member of the Cotton CRC Finance and Audit Sub-Committee.

Mr. Stuart Higgins (2005-2009)

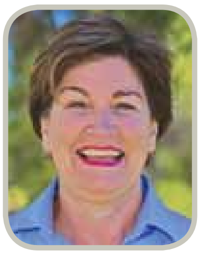
B.Ag.Sc, G.C.R.Sc.(CP)

Stuart Higgins operated a Best Management Practices irrigated cotton and grain property on the Darling Downs in Queensland. Stuart has been recognised for his work on irrigation water use efficiency improvements and for establishing initiatives for engaging the wider community in complex agricultural issues, mainly through ABC Radio National. He has consulted in Asia, Africa and Central Asia for various non-government organisations on irrigation infrastructure assessments and agricultural value chain analysis. Stuart is a graduate of the Vincent Fairfax Ethics in Leadership Program and Chair of the Australian Cotton Industry Council's Best Management Practices Advisory Panel. He was Chairperson of the Cotton CRC's Technology and End User Specialist Advisory Panel and a member of the Human Resources Sub-Committee.

XI. company management team

Philip Armytage

Philip Armytage held the position of Chief Executive Officer of the Cotton Catchment Communities CRC Ltd since January 2008. He held full responsibility for organisational performance, governance and the achievements of the CRC. Philip developed and nurtured a highly effective team who created and implemented highly efficient systems to deliver the outcomes of the CRC. As CEO, he had primary responsibility for developing and maintaining linkages and harmonious collaboration between large numbers of CRC partner organisations. With a commercial background, in marketing, sales and development, Philip worked with the Cotton CRC Board of Directors to develop strategies to deliver the contracted outcomes of the centre while ensuring world's best practice in governance.



Kym Orman

Kym joined the Australian Cotton CRC in 2001 as Executive Officer and then became the Cotton CRC's Company Secretary/Business Manager in 2005. As Company Secretary she was responsible for the governance of the Cotton CRC, including reporting to, and minute taking for, Audit Committee meetings and minute taking for Governing Board meetings. As Business Manager she was responsible for the quarterly Board financial reporting, as well as annual audited statutory financial accounts. She managed the Intellectual Property processes, including the IP register, and oversaw project agreement monitoring and progress payments.

Kym has 19 years experience in cotton research administration. She was Business Manager for the Cotton Research and Development Corporation prior to joining the previous Cotton CRC as Execuive Officer in January 2001. She was instrumental in the successful bid for the Cotton Catchment Communities Cooperative Research Centre in 2004–2005 and successfully completed the set-up of the new $72 million CRC.

Peter Gregg

Peter was seconded from the University of New England (UNE) as full-time Chief Scientist of the Cotton Catchment Communities CRC in 2005. Commencing as a lecturer at UNE in 1980, Peter progressed through the academic classifications reaching Level E (Professor) in 2005. As a researcher and Program Leader in both the two previous Cotton CRCs, Peter's knowledge of collaborative research made him an ideal Chief Scientist for the Cotton CRC.

In his role as Chief Scientist Peter has been responsible for the scientific leadership within the CRC, providing direction to Program Leaders and ensuring that the research quality was of the highest standard and embraced strong collaboration. Peter also provided mentoring and coaching for postgraduate and junior researchers. As a member of the company management team he provided assistance with strategy development, monitoring and evaluation as well as research implementation. Peter also continued his own collaborative research through the life of the Cotton CRC, with one major achievement being securing full registration and commercial sales of a moth attractant Magnet®.

Paula Jones

Paula Jones joined the Cotton CRC in October 2006, first as Catchment and Community Program Leader and then later as Chief Operating Officer and Community Program Leader. In her role as Program Leader, Paula led multidisciplinary research and end users teams to establish and manage projects in the CRC's two new Catchment and Community research portfolios. As Chief Operating Officer, Paula oversaw the delivery of all Cotton CRC DIISR outcomes and worked closely with CRC researchers and partners to develop an implement the CRC's monitoring and evaluation program.

Lynda George

Lynda joined the Australian Cotton CRC in 2001 as administration assistant to both the CEO and Business Manager. She became Project Administrative Officer for the Cotton Catchment Communities CRC in 2005, progressing in 2009 to her final role of Project Management Officer (PMO).

In her role as PMO, Lynda provided general support through various tools and techniques to assist with the planning and execution of the Cotton CRC's 428 projects. She provided administrative management of project contracts and monitored and reported on the performance of all research andextension projects.

Belinda Graham

Belinda joined the Cotton CRC in 2006 as the company Accountant supporting the Business Manager. With a focus on maintaining good relationships with research providers and participants, Belinda worked closely with other team members to manage the payables and receivables functions, ledger maintenance, BAS returns, payroll and insurances.

Prior to joining the Cotton CRC, Belinda had over 25 years of experience across a range of functions including audit, farm office management and logistics.

XI. company management team

Robyn Smith

Robyn joined the Cotton CRC in September 2009 as Executive Assistant to the CEO as well as Project Administration Assistant and more recently, Bookkeeper. Robyn was responsible for organising all staff, management and board meetings, including minute taking for the Company Management Team; travel requirements and the general day-to-day management of the office. In addition, Robyn assisted the PMO with implementation of research projects and consultation agreements as well as the processing of all accounts payable and receivable for the Cotton CRC Accountant.

Jane Trindall

Jane became the Cotton CRC Catchment Program Leader in 2010, managing projects, investment partners and research providers. The Catchment Program included research to better understand groundwater, surface water, water quality, ecosystem services and projects to provide guidelines for farmers, CMAs, NRM bodies and other decision makers. Prior to this role, Jane co-led a major Namoi CMA/Cotton CRC project to invest in NRM projects conducted with farmers to achieve significant NRM on-ground outcomes in line with the Namoi CMA Catchment Action Plan.

Yvette Cunningham

Yvette joined the Cotton CRC in 2007 as Communications Officer. In this role Yvette was responsible for planning and implementing the Cotton CRC's communication strategy. In 2009, Yvette took on the role of Adoption, Education and Communication Manager, which increased her portfolio to overseeing the education, training and adoption projects across the CRC. Yvette worked closely with extension personnel, researchers and students to promote CRC research outcomes and extension activities. The effective communication of research findings assisted significantly in the rapid adoption of best practice.

Lewis Wilson

Lewis was joint Program Leader for the Farm Program of the Cotton Catchment Communities CRC and previously a Program Leader forthe Sustainable Farming Systems Program in the Australian Cotton CRC. He is also Research Program Leader with CSIRO Plant Industry where he leads the Cotton Management and Improvement Program. Lewis is an entomologist and has worked on developing integrated pest management systems in cotton for the past 26 years. His research interests include non-target effects of pesticides and transgenics, pest ecology, development of sampling strategies and economic thresholds, insecticide resistance and host plant resistance. He has also served as a member of the Cotton Industry Biosecurity and the Transgenic and Insecticide Management Strategies Committees for many years.

Graham Harris

Graham Harris was joint leader of The Farm Program for the life of the Cotton CRC. He has 31 years of extension experience in irrigated crop agronomy and economics within the Queensland Government, Department of Employment, Economic Development and Innovation (formerly the Department of Primary Industries and Fisheries). Graham served in irrigation communities in southern, south-eastern and central areas of Queensland during that time. He currently leads the DAFF Queensland Irrigated Farming Systems Team, which comprises research and development staff.

In 2005, Graham used his Swire Group Churchill Fellowship to study precision irrigation technologies in the USA and Israel. Within The Farm Program he oversaw research within the Water Use Efficiency, Crops and Soils and Resilient Farming Systems sub-programs.

In addition to his CRC Program Leadership, he is working in the Water Use Efficiency Investment for Healthy HeadWaters, Rural Water Use Efficiency 4 and High Yielding Irrigated Grains projects.

Dallas Gibb

Dallas Gibb provided leadership to the Product Program from 2006. He first become involved in the Cotton CRC program in 1993 as a cotton extension office in Moree and then as the CRC's first National Cotton Extension Specialist in 1995. Across an 11-year career with NSW Department of Primary Industries he held various positions including the Program Leader for Research/Extension Cotton and Director Centre of Excellence for Cotton, Pulse and Oil Seed Improvement in Narrabri. In 2006 Dallas joined the R&D leadership team at the Cotton Research and Development Corporation.

Dallas was an integral member of the strategic planning and bid committee that established the Cotton Catchment Communities CRC. His initial role was in the development of the Catchment Program for which he was the initial Program Manager before taking on his role within The Product Program. He believed the most significant benefits derived through the CRC program is the active cooperation and collaboration that has been achieved across a diverse range of researchers and organisations.

Dallas established his own business in 2008, TechMAC Pty Ltd, and assists a range of public and private organisations in R&D management, product commercialisation and intellectual property management.

XII.

our legacy

There now exists a generation of cotton growers, researchers, extension staff and industry personnel who have never worked in the Australian cotton industry without the presence of a Cotton CRC. Now in 2012, after 18 years of being involved in the CRC program, there is the opportunity to reflect on the benefits this long term investment in collaborative research has delivered to the cotton industry, its catchments and communities.

The achievements of the Cotton Catchment Communities CRC from 2005 to 2012 have been many and varied including:

- Adding over $1 billion worth of value to the cotton industry, its catchments and communities.
- A 40% improvement in water use efficiency by the cotton industry.
- Developing software and systems to map underground aquifers and their recharge mechanisms in 3D.
- Establishing an indigenous traineeship program within the cotton industry.
- Reducing contaminants in raw Australian cotton fibre by 50%.
- Training over 60 PhD and Masters Students from 10 Universities.

XII. our legacy

The one thing these achievements have in common is that they were all a result of people working together for the greater good of the industry, the environment and rural communities. This display of good will, commitment, dedication, ingenuity and most importantly collaboration is what really underpins the success of the Cotton Catchment Communities CRC and its two earlier CRCs.

The establishment of common goals which override individual vested interests is one of the key drivers of this success. These common goals created a platform from which the successive Cotton CRC's have been able to change people's attitudes to the way in which research is conducted, support transformational science, and create a more outward focussed industry through its diverse research and partnerships.

Given the broad scope of this Cotton CRC, its legacies are many and varied. There are however a number of legacies which we are most proud. This is because they represent the way the Cotton CRC's mode of operating has changed the way research and development is now conducted. These legacies include:

- A new approach to the development and delivery of research.
- Fast tracking and supporting the redevelopment of the cotton industry's *my*BMP program.
- Establishing new industry, environmental and community partnerships.
- Supporting collaboration through events such the Sustaining Rural Communities Conference and Cotton CRC Science Forum for sharing information, developing skills and connecting with all sectors of the community.

Development and Delivery

The structure and organisation of the Cotton CRC National Cotton Extension Network was developed during the term of the Australian Cotton CRC; however, as the new CRC began to implement its wider remit, the team evolved and new roles including the delivery of environmental and social research emerged.

The extension network allowed for collaboration across state boundaries and acted as a link for many researchers functioning in different states. Yet as the drought hit, team numbers declined rapidly and a new approach was required to disseminate information.

In 2009, the Cotton CRC, CRDC and Cotton Australia worked collaboratively to restructure and refocus the extension and knowledge system services, resulting in the establishment of the Development and Delivery Team (D&D). The new team moved away from regionally based extension to focus more on specific target areas at a national level. The new commercially oriented system focused on campaign-based development and delivery. This was a whole new way of operating for the industry and while still in its infancy it marks a significant change in the way industry research will be delivered in the future.

*my*BMP

The Australian Cotton Industry's Best Management Practices (BMP) Program was established in 1997, with the initial purpose of improving the industry's management of pesticides. It was developed as a voluntary farm management system providing self-assessment mechanisms, practical tools and an auditing process to guarantee that cotton is produced using best practice. The program was based on a process of continuous improvement using a 'plan–do–check–review' management cycle.

In 2010, the new *my*BMP was launched as a web-based management system based on the original BMP manual. The original manual was replaced with a user friendly, regularly updated, web-based tool. *my*BMP now provides a centralised location for growers and industry personnel to access the latest information and research, find solutions to challenges that may arise and provide a wide variety of tools and features to help industry members operate at optimal efficiency. Most importantly, as a web-based system, it is flexible and easy to use, able to record and distribute information instantly, provide updates and make immediate changes as they are required.

The Cotton CRC, in conjunction with CRDC and Cotton Australia, were the key drivers of the new *my*BMP and through the Cotton CRC were able to fast track its development during a time when the industry was facing considerable financial hardship. The program now serves as the key mechanism through which all research will be delivered to growers in the future.

> "If you want to be incrementally better: Be competitive. If you want to be exponentially better: Be cooperative."

New Partnerships

One of the hallmarks of the Cotton CRC was its capacity to bring diverse partners to the table and find a common base from which they could work together to achieve an agreed goal. While this sounds relatively straight forward, the realities of undertaking this are frequently akin to herding cats. This is especially challenging when many of these partners were new to the cotton industry, had never worked with a CRC before and there were very few established relationships.

Despite these challenges, over the life of the Cotton CRC, we brought together 190 different organisations representing three tiers of government, cotton industry bodies, research agencies, other CRCs, SME's, aboriginal groups, community organisations, regional NRM bodies, mining companies, media groups, adult education providers and schools. This is a mammoth effort after only 7 years of operation.

Many of the partnerships established will continue in various forms beyond the life of the Cotton CRC. For those that don't, we have provided all partners with an opportunity to 'walk a mile in the moccasins' of others and gain a greater understanding of industry, environmental and social issues in cotton growing regions. These new partnerships have also demonstrated that people can work together for the greater good of the industry, environment and community.

XII. our legacy

Supporting collaboration

Collaboration doesn't just occur because you 'will' it to happen. It takes time and requires the development of lasting relationships. In a similar way to growing a cotton crop, you need to plant the idea in the right environment and provide adequate resources and care before its starts to flower and is ready for picking.

The Cotton CRC strove to create these collaborative environments through activities such as the Sustaining Rural Communities Conference, Science Forum, Groundwater workshops, Discipline Reviews, Project Inception meetings and Project Steering Committees. These events not only create the right growing environment but also help mobilise and harness the right resources (people, money and partners). Most importantly these activities are based on a willingness to participate, share ideas and work together. All of which enables the crop and ideas to yield well and be of the highest quality.

In closing....

While we are only able to provide here a snapshot of the legacies of the Cotton CRC, the aspect that we are most proud about is the strong commitment from our participants and partners to continue this work beyond the life of the Cotton CRC. This commitment is the ultimate measure of the value of the Cotton CRC and makes all the effort so worthwhile and rewarding.

The Cotton CRC is proud of the role it has played in the cotton industry, its catchment and communities. Collectively we have collaborated to achieve significant outcomes both for the industry and the regions in which it operates.

We can confidently say we have created 'prosperity through innovation'.

So this is our story...

Dr Paula Jones, Chief Operating Officer
Cotton Catchment Communities CRC, May 2012

NSW DPI and CSIRO researchers with Hon Simon Crean talking cotton.


CRC

Professor Peter Gregg,
Dr Lewis Wilson,
Graham Harris,
Dr Ian Taylor & Dave Wigginton

chapter one

farm research program

The Farm Program involved scientists from a range of disciplines and partner organisations with the aim of countering the new challenges emerging in Australian cotton production. A new generation of genetically modified (GM, or transgenic) technologies were being introduced, but the value proposition for growers was not straight forward. The farming system needed to adapt to make the most of the opportunities these technologies presented. At the same time, the irrigation sector, including cotton, also needed to address the high expectations for continued improvement in water use efficiency in the face of drought, changing government policy and possible climate change. Practice changes, backed by scientifically robust principles were needed to grow the crop's productivity in ways that were repeatable across seasons and regions and were demonstrably sustainable.

The Program built on the success of the previous Australian Cotton CRC which focused on; *Growth in Northern Australia, Innovative Technologies and Farming Systems.*

The CRC framework, combined with a dedicated program management team committed to facilitating interaction and collaboration among key researchers and partner organisations, resulted in the successful delivery of key achievements including:

- Improvements in integrated management systems for cotton pests (insects, weeds and diseases) that are profitable, sustainable and demonstrably less reliant on inputs;
- Developments and demonstration of tools that increase on farm water use efficiency;
- Demonstrating high yielding cotton-legume cropping rotations which reduce the need for fertiliser inputs, improve soil health and sequester carbon in the soil;
- Fine tuning of resistance management tactics to ensure the continued effectiveness of transgenic technologies and the major benefits they bring to cotton farm businesses and to the environment;
- Developing and demonstrating successful methods for cotton production in a range of potential new growing areas.

Farm Program Leaders

Peter Gregg	2005 – 2012
Lewis Wilson	2005 – 2012
Graham Harris	2005 – 2012

PROGRAM AIMS WERE:

1. Developing cotton farming systems with enhanced resilience and adaptive capacity to climate variability and change.
2. Enhancing understanding of the water balance in cotton farming systems and developing tools to maximise water use efficiency.
3. Developing systems to improve the management of plants and soil that ensure profitable production and stewardship.
4. Developing improved integrated pest management systems for cotton pests (insects, diseases and weeds) which are profitable, sustainable and less dependent on inputs.
5. Developing and introducing novel commercial products which enhance crop management and profitability.

GM brings an industry revolution

- Stewardship of GM cotton technologies

One of the most significant changes in the Australian cotton industry has been the introduction of GM cotton. Cotton paved the way for the introduction of GM technology to Australian agriculture. The first transgenic cotton to be grown in Australia was Ingard® in 1996. Ingard cotton contained a single Bt gene which expressed Cry1Ac, a protein that provided protection against the key insect pests of cotton, caterpillars of moths such as *Helicoverpa armigera* and *H. punctigera*. These pests feed on developing bolls, and can completely destroy a cotton crop.

For early season weed control the addition of a gene that makes cotton tolerant to Roundup Ready® Herbicide (which contains the commonly used activate ingredient glyphosate) further changed the cotton landscape. With support from home-grown research, these international technologies, introduced by Monsanto Australia Pty Ltd, have changed the face of the Australian industry during the time of the Sustainable Cotton, Australian Cotton and Cotton Catchment Communities CRCs.

Interestingly these GM technologies promised neither revolutionary increases in yield potential nor major cost savings. What they did offer growers was protection against the big losses to insects and weeds that had occurred in some years, helping to plan crop budgets, consistently achieve yield expectations and adding

GM cotton in Australia: a history

1996 Australia's first GM cotton, Ingard®, was released commercially, containing a single gene from the soil bacterium Bacillus thuringiensis (Bt). Ingard underwent a rigorous testing and approval process by regulatory authorities before its release was permitted under the Commonwealth regulatory system. Ingard® was available between the 1996–97 and 2003–04 seasons. During those eight seasons, Ingard® crops required 44 per cent less insecticide and miticide than conventional crops.

2000 The first genetically modified herbicide-tolerant cotton was introduced after a period of research and cultivar development under regulatory permits. There has been a steady increase in the area planted to Roundup Ready® and its successor Roundup Ready Flex® as variety availability has improved. Since its introduction, there has been an estimated 30 per cent reduction in overall herbicide use and a 46 per cent reduction in the use of residual herbicides.

2002 Bollgard II® technology containing two Bt genes of resistance was approved for commercial use.

2003 Bollgard II® varieties became available to cotton growers for planting. Since their introduction they have required 85 per cent less insecticide than conventional cotton varieties.

significantly to the flexibility of management. They offered a strong platform on which to base the holy grail of management principles: strongly integrated pest and weed management systems.

Importantly, GM technology offered the potential to reduce the use of many insecticides and herbicides, particularly some environmentally problematic ones. It was apparent that GM cotton varieties had the potential to dominate the industry, but this raised new issues for the future of cotton production. These included:

- the need to guard the technology against resistance, both for insects and weeds;
- the lack of science to support new management practices using transgenic varieties under Australian farming systems;
- the broader ecological changes in the landscape as a result of changing cotton management practices.

Australian Cotton CRC CEO and current CRC Board Director, Dr Gary Fitt, was a key driver of the research that led to the adoption of Bollgard II®. He recalls the development and introduction of this revolutionary technology as an exciting time for both growers and researchers, providing a solid platform for IPM (Integrated Pest Management) and promising to remove the ever-present threat of catastrophic crop damage.

Helicoverpa caterpillar borrowing into boll to feed on seed.

Managing Helicoverpa resistance

The impetus for adopting insecticidal GM technology was the speed with which the pest *H. armigera* evolved resistance to insecticides during the preceding decade. Pest control was unsustainable, threatening the industry's continued existence. The use of the original one gene cotton, trade name, Ingard®, was capped at 30 percent of total cotton acreage because of concerns about its vulnerability to resistance. Ingard® was purposely superseded seven seasons later by Bollgard II®, containing an additional Bt gene. However there was still an appreciable risk that *H. armigera* would develop resistance.

The Bt proteins in Bollgard II® are expressed in the plant's tissue, which means there is constant selection pressure for survival of resistant individuals. Professor Peter Gregg, said, *"H. armigera in particular had a long history of resistance to insecticides delivered as sprays, and had destroyed cotton industries in many parts of the world. Bt is just another insecticide, even if it's delivered in a novel way. The potential risk to our industry was obvious".*

Research led by the Australian Cotton CRC and the technology owner, Monsanto Australia Pty Ltd, enabled the collective development of a Resistance Management Plan (RMP) to enhance the robustness of the two-gene cotton. Management practices designed to stymie the survival of resistant individuals in the pest population were introduced as conditions of using the two-gene cotton.

At the start of the Cotton CRC in 2005, scientists and industry wanted to see the GM technology adopted more broadly but also wanted to ensure that it would remain durable for many years. Over the course of the Cotton CRC entomologists continued to research options for resistance management and also contributed to the industry's regular updating of the RMP.

Resistance management plans impose limitations and requirements for management on farms that grow Bollgard II®. These include mandatory growing of refuges to produce susceptible insects, defined planting windows, restrictions on the use of foliar Bt sprays, mandatory cultivation of crop residues and the control of volunteer plants.

Pigeon peas have evolved to become the most prevalent refuge type throughout the cotton industry, primarily because they have been shown to be highly productive, thus allowing a smaller area of this refuge type to be grown in comparison with other refuge types.

A key component of RMPs is that growers planting Bollgard II® must also plant a refuge crop. A refuge crop is a crop grown deliberately to produce moths that are susceptible to the proteins Cry 1AC and Cry 2Ab contained in Bollgard II® cotton. It may seem counter-intuitive to breed pests that have been so damaging to cotton and many other crops over the years. However these susceptible insects play an important role in slowing the development of resistance in the larger *Helicoverpa* population. Producing susceptible moths (those that have not been selected for resistance with either of the Bt proteins), provides the opportunity for non-selected adults to mate with any potentially resistant moths emerging from Bt cotton, and genetically dilute resistance. Little was known about the mating interactions of moths emerging from refuge crops and Bollgard II cotton. Given that the production of moths from the refuge and the mating patterns of these moths form such an important component of the success of Bollgard II® technology, the Cotton CRC and its industry partners have made significant investments in research to better understand moth production, moth behaviour and factors leading to successful mating.

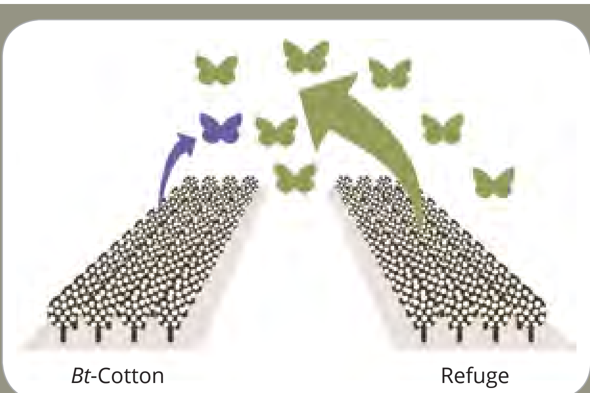
Research by Dr Geoff Baker, Dr Mary Whitehouse and Colin Tann (CSIRO) showed that moth production in refuges was highly variable. They investigated the productivity of the different refuge types commonly used within the industry; unsprayed pigeon peas, unsprayed cotton and sprayed cotton. A key finding was that, while poorly managed refuges were less productive, well managed refuges were sometimes unproductive, too. Studying refuge crops across the St George growing area in southern Queensland, they investigated how moths behave in a cropping mosaic, that is a mix of cotton, refuges and other host crops, with the aim of developing RMPs that work at a landscape level not just on an individual farm level.

The research team also explored alternative refuge options such as splitting unsprayed cotton into early and late planted sections. Pigeon peas have evolved to become the most prevalent refuge type throughout the cotton industry, primarily because they have been shown to be highly productive, thus allowing a smaller area of this refuge type to be grown in comparison with other refuge types. This work found the assumption that pigeon peas were more productive than other refuge options did not always hold true, but also that alternative strategies failed to increase overall refuge productivity. Reasons for the variability between refuges were unclear, which led to a new PhD project (Dominic Cross) to evaluate options to increase the productivity of refuges, such as reducing natural enemies in refuges to increase moth production.

Dr Mary Whitehouse said as a result of this work, growers were advised that, rather than seeking new options for refuge crops, they should ensure that current refuges are managed to the best of their ability so they can produce the maximum numbers of susceptible moths.

'Looking after refuges, including weed control, nutrition, timely irrigation and all factors that make the refuge attractive to female moths laying eggs is the key to ensuring that they are effective', says Mary.

Despite the lack of widespread resistance, surviving *Helicoverpa* larvae were sometimes being found in Bollgard II® crops, and occasionally exceeded economic threshold levels. This was a perplexing problem for consultants and growers within the industry. Laboratory tests showed that these larvae were not resistant to the two proteins in Bollgard II® prompting entomologists to ask – why and how were they surviving? Once again the CRC with its key participants facilitated the development of a research project to answer these questions and to determine whether existing pest thresholds were adequate for control of *Helicoverpa* in Bollgard II® cotton.



Moths produced from refuges dilute resistance genes in the population.

PhD student Baoqain Lu was recruited to investigate these questions. Working alongside highly experienced scientists he found that some feeding larvae regurgitated cotton tissue containing Bt proteins, which enabled them to continue test feeding until they located plant structures such as flowers that express comparatively low levels of the Bt toxins. Combined with seasonal variations in the phenotypic expression of proteins, this behaviour allows some susceptible larvae to survive. Experiments with real and simulated pest damage showed that current thresholds were valid, and this advice has been extended to growers in key publications such as our annual Cotton Pest Management Guide.

The advent of Bollgard II® cotton also challenged some facets of our understanding of pest ecology. Historically populations of *H. armigera* build in successive generations, reaching high numbers in late summer. However, long term monitoring by Colin Tann, a member of Dr Baker's team, is showing that since the introduction of Bollgard II® cotton these populations no longer develop. Geoff says:

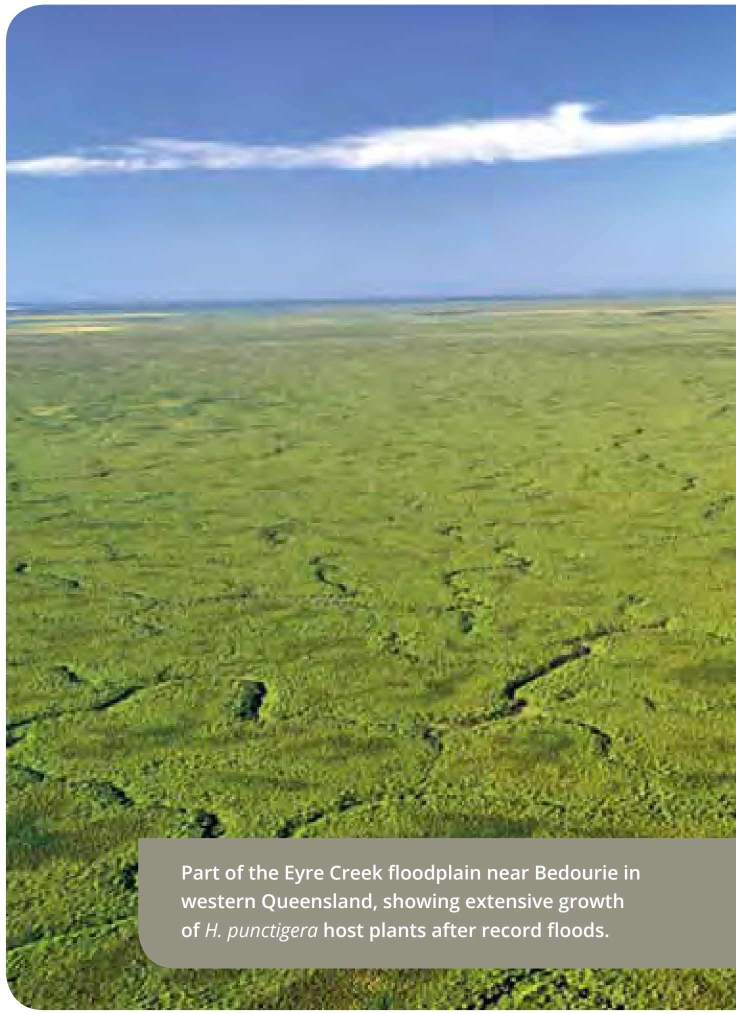
'*Historically, successive generations of H. armigera built up over the cotton season reaching very high and destructive numbers in late summer. Our long term monitoring though has showed that since the advent of Bollgard II® this is no longer the case and large populations no longer develop suggesting that a landscape level of suppression is occurring due to the widespread adoption of Bollgard II®.*'

Helicoverpa punctigera on the other hand, was believed to develop large populations in far inland areas, which migrated to cotton regions in spring. As these moths had not been exposed to Bollgard II® it was believed they should be susceptible to the Bt proteins. By mating with any potentially resistant moths remaining in the cotton regions from the previous season, any resistance would be diluted genetically. However, Dr

Collecting *H. punctigera* from annual verbine in the flood plain of Eyre Creek, west of Birdsville. The plants in the foreground have been extensively damaged by the caterpillars, which breed on this and other native host plants in inland Australia, and then migrate as moths to cotton producing areas.

Sharon Downes and Dr Rod Mahon demonstrated that the initial resistance frequencies in this species to Cry2Ab were higher than expected, and have increased over time, challenging this theory. Surveys of *H. punctigera* abundance in western Qld after the drought years, by Professor Peter Gregg, Dr Alice del Socorro and PhD student Kris Le Mottee suggested that the scarcity of plant hosts in these inland areas due to dry conditions meant there was limited migration to cotton regions during the drought, and hence little dilution. Surveys have continued following recent rains and found widespread populations of *H. punctigera* larvae in these inland areas, but interestingly rains have allowed continued host growth and second generations of larvae are being produced locally, indicating moths have not migrated. This is causing us to rethink the migration behaviour of this pest.

While insects carrying resistance alleles can be found in the field, there has been no indication of crop failures or yield losses due to resistance, which vindicates the cautious approach taken. In 2012, these RMPs continue to be acknowledged as the most robust and scientifically based in the world. Aided by the latest techniques for integrated pest management (IPM), the industry is using up to 85 per cent less insecticide¬ compared to pre-Bt cotton – a win for cotton growers and for the environment.



Part of the Eyre Creek floodplain near Bedourie in western Queensland, showing extensive growth of *H. punctigera* host plants after record floods.

farm program
chapter one

Fleabane, in particular, is tolerant of glyphosate and its biology and ecology was investigated by PhD student Todd Green (UNE) to provide greater understanding of other management strategies that may be effective in reducing the threat from this weed.

Resistance management in weeds

Roundup-Ready Flex (RRF) technology, allowing season-long, over-the-top application of glyphosate, had very strong uptake by industry, currently 99% adoption, and has dramatically altered subsequent weed management strategies. Glyphosate is now the herbicide of choice permitting effective weed-free fallows in both dryland and irrigated systems. The heavy reliance on glyphosate raises the risk of weeds developing resistance to it in cotton producing areas. Five resistant weed species have now been confirmed in dryland systems, including awnless barnyard grass, liverseed grass, flaxleaf fleabane, windmill grass and annual ryegrass, which are all present in many cotton growing regions.

Research led by Cotton CRC supported researchers Dr Steve Walker and Dr Jeff Werth has been very effective in developing strategies to manage these resistant weeds, including the use of alternative herbicides. Glyphosate resistance is a significant threat to farming profitability, and the recent emergence of glyphosate resistant weed populations in northern cotton and grains farming systems has a direct cost to affected growers. If growers can prevent or delay the onset of glyphosate resistant weeds on their farms, they will be able to continue to derive maximum benefit from glyphosate, with the cost-effective benefits that this brings.

In irrigated cotton, with the wide window of opportunity for application provided by Roundup-Ready Flex®, there was no clear basis for deciding when to apply glyphosate to optimise benefits afforded by the technology while minimising the risk of resistance developing. To keep resistance at bay the CRC embarked on a number of projects. Research initiated by Dr Ian Taylor and subsequently led by Mr Graham Charles developed weed control thresholds for cotton.

What is Roundup Ready FLEX Cotton?

Roundup Ready cotton, which was released in 2000, contained one copy of the gene, cp4 epsps, which provides tolerance to the widely used non-residual herbicide, glyphosate. Roundup Ready FLEX® cotton contains two copies and was first released in limited quantities for the 2006–07 season. It has prolonged expression of the cp4 epsps gene and is tolerant to glyphosate at later stages of growth. This means the window in which glyphosate can be applied directly to the cotton crop is longer, giving growers increased flexibility in timing herbicide applications as part of integrated weed management. Cotton varieties carrying Roundup Ready FLEX® are available both with and without Bollgard II.

This required extensive evaluation of the effects of different weed densities, size and types on cotton yield, taking into account time of season. The outcome was weed control thresholds that provide industry with an objective method to assess the need for weed control and hence optimise glyphosate use, avoiding over-application with its associated costs and resistance risk.

Graham Charles said

'The thresholds take the guess work out of weed management, and enable growers to identify below-threshold weed populations which don't require immediate control. This is a huge step forward for the Australian cotton industry. It is particularly valuable for inexperienced growers in the newer areas and as a tool to guide new agronomists.'

The significant risk of glyphosate resistance has also driven development of tools to help growers assess and manage the risk. The PhD project of Dr Jeff Werth showed that reliance on glyphosate alone dramatically shortened the life of this technology, but including of one or more alternative weed management options dramatically prolonged its effective life. In irrigated cotton systems resistance to glyphosate is more easily managed because its predominant use is in-crop – hence weeds are more likely to be controlled by other herbicides and when the field is cultivated to clean up furrows, or hand chipped. Understanding how resistance develops and assessing a grower's individual risk are important components of a resistance prevention or management program. The Glyphosate Resistance Toolkit was developed by Dr David Thornby.

This web-based risk assessment tool allows growers and their advisors to enter information on their current practices (including crop rotation, crop density, and weed control tactics) and identify which weed species they typically control. The tool will then calculate a glyphosate resistance risk score for each paddock tested, and a level of risk for each weed identified.

David Thornby said

'The tool also provides information on how risky each of the phases in the grower's rotations are, which helps growers identify where they may be able to make useful changes. The user's results and some non-identifying information entered into the tool are collated into a database.'

'For all growers, but especially dryland growers, retaining glyphosate as a useful herbicide is directly related to farm profitability, not only for reducing yield losses due to weeds, but for maximising moisture retention in low-tillage cropping,' said David.

Nevertheless, an increasing number of growers will be forced to deal with glyphosate-resistant weeds. The team has explored a range of management strategies for resistant biotypes. Dr Jeff Werth's work demonstrated that residual herbicides are effective on resistant Awnless Barnyard Grass. These resistant weeds, while undesirable, can be managed effectively. Further work showed that a 'double knock' strategy of glyphosate followed by one of several other herbicides provided effective control of this weed in fallows. This has been widely adopted in cotton fallows and grains systems. In cotton crops this is not feasible and the scientists found that use of residual herbicides provided the best control.

Biosecurity

- Emerging Pests, Weeds and Diseases

The dramatic uptake of Bollgard II® cotton and the equally dramatic 85% reduction in insecticide use, ironically, has allowed some pests formerly controlled by insecticides applied to control *Helicoverpa*, to survive. Cotton CRC researchers have be aware of these impending threats and have spent considerable time learning more about the ecology of potential pests such as mirids, Silverleaf Whitefly, Green Vegetable Bug, Pale Cotton Stainers and Mealy Bugs.

New controls needed for mirids

For the first time, sucking pests such as the green mirid (Creontiades dilutus) were surviving and reproducing, leading to *potentially* damaging numbers. Mirids are capable of causing major damage by feeding on developing cotton squares and bolls, causing them to abort or deform, resulting in potentially significant yield losses.

A lynx spider eating a mirid

In China, mirids became a serious pest following the introduction of GM cotton, and opponents of GM technology have considered this to be evidence against its sustainability. The emergence of a different species was observed in Australia: the green mirid. Little was known about the ecology of mirids and therefore how their role would change with the introduction of Bollgard II® cotton. Would they remain only a minor pest, or a threat to the whole system of transgenic cotton? We had only a limited range of broad-spectrum insecticides available to control mirids and the potential resistance risk was unknown. Available insecticides usually resulted in a dramatic decline in beneficial insects, increasing the risk of mite, aphid or whitefly outbreaks. This raised concerns about effective sampling, thresholds and control options.

Through the Cotton CRC, research led by Dr Moazzem Khan (DAFF Queensland) and Dr Brian Duggan (CSIRO) evaluated the effect of mirid populations on yield and the potential for cotton to compensate for damage. This allowed development and validation of thresholds for stages of crop growth and calibration of the thresholds for the different sampling methods.

Thresholds based on mirid numbers, crop development and fruit retention levels provided a guide to when growers should control for mirids to avoid yield penalties.
Dr Moazzem Khan's research showed that lower rates of registered insecticides combined with salt or petroleum spray oils (PSOs) gave good control with lower negative effects on beneficial insects – a win-win.

'We now have better understanding of Mirid damage at different crop stage. Early boll stage is the most critical stage for Mirid damage. Mixing salt with registered chemical allows the chemical rate to be reduced by up to 70 per cent without reducing effectiveness which is a big saving to the industry," says Moazzem.

However, pest surveys showed that despite effective sampling and threshold information, many insecticides were applied at below threshold levels – more than 85 per cent below recommended thresholds, according to Dr Mary Whitehouse (CSIRO) – partly as 'insurance' and partly due to incorrect matching of sampling and thresholds. This gave no yield benefit and increased the risk of outbreaks of other sucking pests.

'This mismatching was largely because pest managers were not allowing for differences between thresholds for visual sampling and those undertaken using a beat sheet' said Mary.

Dr Whitehouse also found that predators, such as lynx spiders and yellow night stalkers were important natural enemies of mirids and the presence of spiders on plants interfered with mirid behaviour, resulting in less crop damage. Her research showed that we needed to place emphasis on giving managers the confidence to use correct mirid thresholds in conjunction with the correct sampling technique.

The ecology of mirids was also a gap in knowledge that was potentially very important for developing management strategies. If mirid populations were localised, pesticide use could select rapidly for resistance. PhD student, James Hereward (University of Queensland), showed that populations of mirids develop in inland regions, particularly on the native plant, *Annual verbine (Cullen cinereum and Cullen australasicum)*, and molecular studies using microsatellites showed that these mirids migrate to cotton regions and should dilute any potential resistance.

'Using genetic markers, I was able to reveal that genetic differentiation exists between mirid populations and that movement occurs between sites, in a dynamic spatiotemporal manner,' James said.

Pale cotton stainers moving to the fore When the widespread outbreak of oale cotton stainers occurred in 2008, the CRC framework enabled collaboration between scientists and extension staff from CSIRO, DAFF Queensland and NSW DPI ensuring information on sampling, damage and management of this pest was quickly assembled from both local and international sources and published for industry – resulting in better control decisions.

Green vegetable bug, *Nezara viridula*, is another minor pest of cotton that has become more abundant since the introduction of Bollgard II cotton. It can cause significant damage to developing bolls, resulting in reduced yield. Research by Dr Lewis Wilson and Tanya Smith (CSIRO) showed that the bugs were present in non-cultivated areas near cotton, especially in remnant native vegetation areas along rivers that have been disturbed and contaminated with weeds. A key outcome is that clearing weed species from native vegetation areas will likely reduce background populations of this pest.

'Within the cotton regions mirid populations on hosts such as cotton and lucerne are genetically the same, suggesting further localised exchange and dilution, which bodes well for resistance management.'

Silverleaf whitefly incursion a biosecurity threat

The risk of exotic pest and disease incursions is a major threat to the cotton industry. Until recently, the Australian cotton industry had been fortunate not to have an emergency plant pest incursion that seriously impacted on the industry. However, the breach of quarantine in the early nineties by the B biotype of *Bemisa tabaci* (silverleaf whitefly) on imported, live poinsettia plants made the industry increasingly aware of the importance of biosecurity threats and preparedness.

The first outbreaks in cotton occurred in the central Queensland region, centred on Emerald and Theodore. This outbreak sparked a vigorous effort by researchers and extension staff to develop strategies to manage whitefly. Silverleaf whitefly reached economic levels in the St George and Darling Downs regions in 2005, in the Namoi and Gwydir Valleys and the Mungindi area in 2009 and the Macintyre and Macquarie valleys in 2010.

Silverleaf whitefly adults and nymphs excrete honeydew that is considered to be worse than aphid honeydew because it has a lower melting point and can cause machinery to gum up and overheat during the processing stage. This affects processing of the lint, as it sticks to machinery and results in severe price and reputation penalties.

Following the first outbreak of silverleaf whitefly in 2001, research projects led by Dr Richard Sequeira (DAFF Queensland), painted a detailed picture of the pest's agro-ecology and bionomics in Australian cropping systems. This knowledge was invaluable in the development of a comprehensive whitefly management strategy that includes sampling tools, conservation of natural enemies, guidelines for the avoidance of disruptive broad-spectrum insecticides and threshold recommendations for cotton production systems.

This management strategy has been instrumental in averting honeydew contamination and minimising adverse impacts on Australia's cotton lint exports.

'The development of the silverleaf whitefly management strategy was a great example of how the Cotton CRC facilitated the successful collaboration of expert from diverse organisations and geographic locations to develop significant and widely applicable scientific outcomes,' according to Dr Sequeira.

The sampling protocols and management guidelines contained within the management strategy were the result of an international collaboration with Dr Steve Naranjo, from the United States Department of Agriculture's Agricultural Research Service in Arizona. Dr Naranjo pioneered the development of mathematical and software modelling tools to aid in Silverleaf whitefly management in Arizona cotton in the mid-1990s.

Silverleaf whitefly adults and nymphs excrete honeydew which can cause machinery to gum up and overheat during the processing stage. This affects processing of the lint, as it sticks to machinery and results in severe price and reputation penalties.

'With advice and technical assistance from Steve, I was able to develop an innovative and practical threshold matrix that links sampling outcomes to control decision and choices,' Richards said.

A concerted research and extension effort by Dr Paul Grundy, Dr David Murray, Zara Hall (DAFF Queensland), Dr Lewis Wilson (CSIRO) and Cotton CRC pest extension specialised Sally Ceeney allowed rapid dissemination of key information about species identification and control options, preventing any cotton from receiving penalties. As a response to these outbreaks, the Cotton CRC initiated new research to quantify breakdown or wash-off of honeydew, to identify the factors causing mortality of immature silverleaf whitefly and to identify alternative control options.

Achieving good pest control requires an understanding of the whole farm system, at both the local and regional scale. At the local scale, a pest species such as silverleaf whitefly needs hosts to feed on through winter. Reducing on-farm hosts for pests through good weed control in fallows and in winter crops will help reduce local survival. Host weeds include sowthistle, marshmallow, bladder ketmia, cow and bell vine, wire weed and cucurbit weeds. Cotton volunteers or ratoons, especially large plants often found along channel banks, can harbour a host a range of pests and diseases. At the regional scale, an area-wide approach to IPM is important, because whitefly will move from crop to crop and farm to farm.

Holding diseases at bay

A range of diseases that can delay growth or result in plant death and reduced yield continue to challenge Australian cotton: the devastating Fusarium wilt *(Fusarium oxysporum* f. sp. *vasinfectum)*, Verticillium wilt *(Verticillium dahliae)*, Black root rot *(Thielaviopsis basicola)*, Alternaria leaf spot *(Alternaria macrospora)*, the aphid-transmitted viral disease Cotton Bunchy Top as well as a range of seedling and boll rot pathogens, including *Pythium* and *Rhizoctonia*.

At present we have no transgenic sources of resistance to these diseases. Conventionally bred varieties resistant to some of the pathogens are available, though there are few solutions for many of the disease complexes resulting in significant yield losses annually. Changes in farming systems have influenced patterns of disease and a fundamental industry strategy to manage and monitor diseases has been biannual surveys of the distribution, incidence and severity of diseases in both NSW and Queensland. These surveys are completed each year soon after establishment and prior to defoliation, and play an important role in understanding changes in threats and the effectiveness of management recommendations. They constitute a long-term record of diseases in commercial cotton crops, with the 2011–1 season marking the 29th consecutive year of surveys in NSW and the tenth year in Queensland.

Aphids are vectors of CBT.

New growth is characterised by small leaves short internodes and small bolls. CBT can have significant impact on yield.

The disease, Cotton Bunchy Top (CBT), spread by the cotton aphid, was first recorded in cotton in 1999. Besides cotton, the only other confirmed host is the weed, marshmallow (*Malva parviflora*); however, changes in the cotton system have increased risks from this disease. The move toward reduced tillage on cotton farms to help conserve soil moisture has allowed cotton plants to survive in fallows. Further, surviving plants that reshoot (ratoons) and volunteers that germinate from fallen seed cotton now contain Roundup Ready genes and thus are not controlled by glyphosate sprays applied to fallow fields or fence lines. As a result, these 'weed' cotton plants are now much more abundant on farms and serve as a reservoir for cotton bunchy top, and as a host for cotton aphids, the vector for the disease. This increases the risk from the disease on farms and in 2010–11 the mild, wet winter promoted build-up of volunteers/ratoons as well as aphids, resulting in a significant increase in the incidence of cotton bunchy top.

While not as devastating as cotton leaf curl disease, cotton bunchy top has served as a useful model for developing biosecurity preparedness for the Australian cotton industry. Further, studying the spread of cotton bunchy top has enhanced our understanding of vector/pathogen relations and how these interactions influence rates of spread of the disease.

Black root rot is a disease that has continued to spread rapidly through the industry with affected fields having poor seedling growth, potentially resulting in reduced yield and delayed crop maturity. It has been considered a significant threat to cotton and other crops in Australia, especially in cooler areas and seasons. CRC scientists, Dr Karen Kirkby and Peter Lonergan, investigated the potential to use biofumigation against black root rot. Biofumigation is the use of a rotation crop that produces substances detrimental to pathogens.

Black root rot is a disease that has continued to spread rapidly through the industry with affected fields having poor seedling growth, potentially resulting in reduced yield and delayed crop maturity.

Diseased seedling Vs non diseased seedling.

Black root rot was also the focus of a major effort by Dr Lily Pereg (UNE) and her team of research fellows and students. They developed methods and research strategies to understand the pathogenicity of this disease and the process and triggers for germination of fungal spores, growth toward cotton roots and colonisation of the roots. Using proteomics and genomics tools, the team showed that in Australia the pathogen strains originated from descendants of a single strain or groups of closely related strains and have most likely adapted to their hosts, with implications for disease severity.

Dr Lily Pereg said *'My team's research has provided the basis and tools for further study to understand the pathogenicity of fungal diseases, with the possibility of exploiting this to develop resistant cotton genotypes or other controls such as soil amendments.'*

'Cotton disease is highly dynamic and thus presents a constant challenge to growers and researchers. It reflects the evolution and variations in farming practices, alternation in cotton varieties and differences in environmental parameters in various cotton growing regions such as temperatures, sunlight, relative humidity, soil biotic and abiotic characteristics, pathogen presence and virulence'.

'The main consequence of the changing nature of cotton disease is the constant challenge it creates: winning one fight might start another! There is a constant need for monitoring for pests and diseases as well as understanding the biology of the disease to be able to develop ways to control it and understanding the local limitations to plant growth so that disease can be minimised by promoting plant growth,' said Lily.

Perhaps the most efficient and cost effective way to minimise disease and pest outbreaks on farm is through good farm hygiene and preservation of beneficial insects. Managing weeds and volunteer/ratoon cotton reduces over-wintering hosts of key insect pests, while the preservation of beneficial insect populations can greatly limit the damage caused by pest populations. To help preserve beneficial insect populations and reduce secondary pest outbreaks resulting from poor insecticide choice, an ID chart identifying the likely magnitude of negative effects of each insecticide against key beneficial groups was created by Cotton CRC scientists.

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Water use efficiency

Water is critical to agriculture and during the drought was the major limiting factor for the Australian cotton industry. Improved water use efficiency allows cotton growers to maintain competitiveness, which is particularly important within the likely constraints of future water availability due to the predicted effects of climate variability and change and water policy reform. A major focus of water research within the Cotton CRC's Farm Program, was to maximise water productivity by growing 'more crop per drop' as well as adopting best practice management to prevent adverse environmental outcomes, while helping to maintain employment and economic activity in local communities.

Water use efficiency improvements through CRC supported research have helped to ensure that the Australian cotton industry remains one of the most water efficient in the world. The success of the CRC's investments is evidenced by the 40% increase in water use efficiency over the last decade.

On-farm CRC water research has been focussed at both the whole of farm and in-crop scales by:

- promoting the measurement of water use efficiency;
- investigating alternative irrigation application systems;
- understanding the movement of water through soil and the potential for deep drainage;
- investigating ways to minimise water losses in on-farm storages; and,
- Improving the productivity of plant water use through better scheduling and improved understanding of plant water relations.

'Measure to Manage'

Fundamental to improved water management is the need to understand existing water use performance. Whilst this sounds simple enough, measuring water performance indicators on cotton farms can be challenging. However, understanding existing water use and performance is essential to be able to determine which irrigation system components might require improvement and the scope to which new research solutions can be applied. The CRC's investment in research comes to fruition when cotton growers are able identify areas of their water management that might be improved and determine how research solutions can be applied. Consequently, support by the development and delivery team has been critical to encourage the adoption of CRC technologies. Over the life of the CRC, members of the Cotton CRC Water Extension Team have undertaken a number of projects to provide water use efficiency information and support to cotton growers in order to facilitate water use performance improvements.

Janelle Montgomery, David Williams and Stuart Bray from NSW DPI collected water use and production information using a new commercial tool called Watertrack Rapid™. The aim was to demonstrate the value of water use efficiency benchmarking to growers through the use of a new tool which had recently become available and was easy for growers to use.

"Water use efficiency benchmarking is critical for individual farmers and the Australian cotton industry as a whole. For individuals, it is important to compare current performance with previous seasons and the performance of others. For the industry, it is important to know how productively water is used, and to demonstrate improvements in water use efficiency over time" says Janelle.

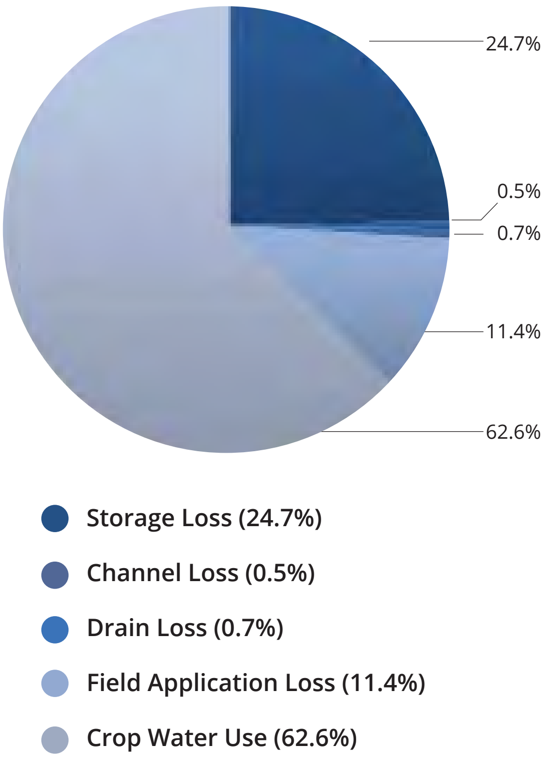
Data was collected for 36 farms, a scale of measurement and collation which had previously only been attempted in a very few research papers as the techniques required were not user friendly. Comparison with these previous studies suggested that the water use efficiency of the industry had improved substantially over less than a decade.

However, their results also showed that the water use efficiency of the 36 farms varied considerably, highlighting the potential for many growers to increase their performance. This work continued in 2009, this time increasing the number of cotton farms to 46 and also for the first time including 24 irrigated wheat crops.

This work was continued through the Cotton Storages Project, although this time the more advanced Watertrack Divider tool was used, which allows water losses to be segregated into different irrigation system components. This is an incredibly important benefit for growers as it allows them to identify those areas of their farm which have the greatest potential for improvement. Across 30 farms, on-farm storages were the largest source of water losses, accounting for an average of 25% of all on-farm water loss.

However, losses from individual storages mainly through evaporation ranged from 5% to 45%, which illustrates the effect that individual storage characteristics and management practices can have on the amount of storage loss. This has important implications for growers, revealing the value of individual measurements in water management decision making.

Figure 1 Water Use



Final use, or loss, of water for all farms as a proportion of the total water available.

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The hidden world of deep drainage

For many years, research which showed that cotton growing soils often have extremely low final infiltration rates was taken to mean that water was seldom lost below the root zone. Vertosol soils in particular were seen to be 'self-sealing' so that water losses to so-called deep drainage were minimal, and that irrigation management practices would have little effect on the small amount of water that might be lost.

However a number of studies and workshops in the late 1990's led to a rethink of this long held view, with the scientific consensus suggesting that significant drainage might indeed be possible. This was an important consideration, as the potential for water movement below the root zone was a hidden water loss for growers as there was no simple way for growers to determine the magnitude of any potential deep drainage problems.

Deep drainage is a concern for cotton growers as not only can valuable irrigation water be lost below the root zone, but pollutants and salt could also be transported to the groundwater. Excessive deep drainage might also cause groundwater tables to rise, along with associated salts. On the other hand, it is also well known that a minimum leaching fraction is essential to prevent accumulation of the salt present in irrigation water.

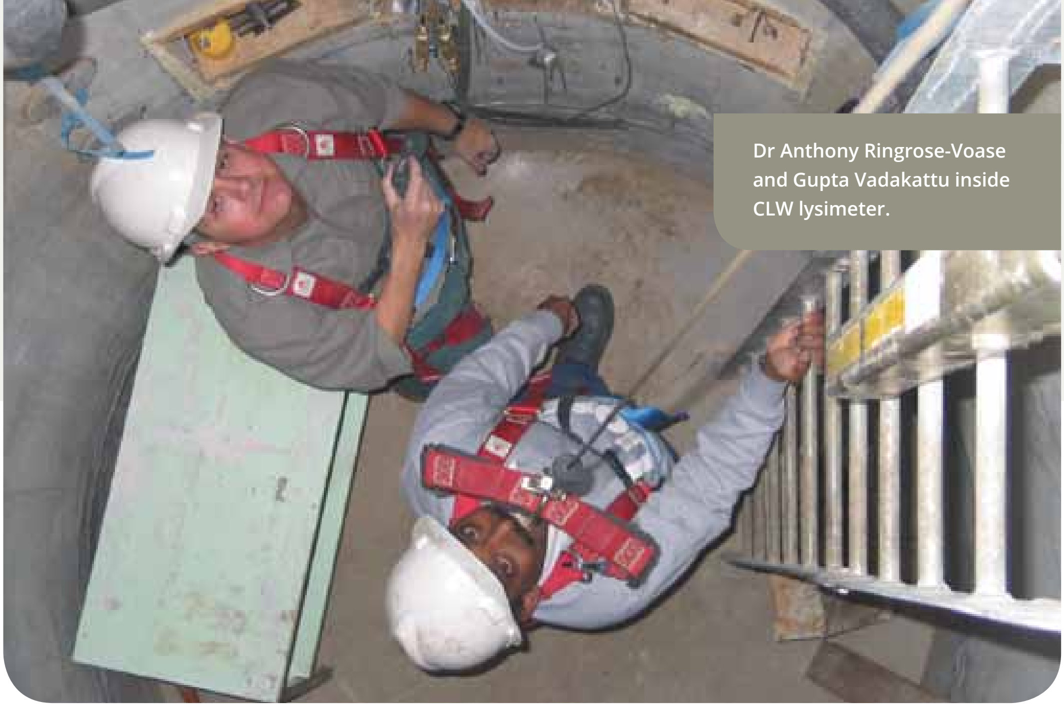
Measuring deep drainage is usually a, difficult and costly task, which has largely been limited to intensively instrumented trial sites on experimental farms. Traditional experimental lysimeters are very expensive and thus their deployment is limited to a very few specific sites. However an innovative approach from DERM scientists Des McGarry and Thusitha Gunawardena involved the installation of 33 constant tension barrel lysimeters on 10 commercial irrigation fields in southern Queensland and on a field at the Australian Cotton Research Institute (ACRI).

Their results showed that deep drainage was highly variable. In only 20 per cent of the 69 sampling occasions across four growing seasons did deep drainage values exceed 100mm (one megalitre per hectare), and the largest recorded deep drainage results occurred in high rainfall seasons. It was also evident that deep drainage was generally higher at the top of the fields, indicating the potential to improve the uniformity of some surface irrigation events.

As experiments continued, Des and Thusitha captured additional layers of data. At one site, they compared deep drainage and soil chloride under surface irrigation and lateral move irrigation, determining that deep drainage was almost non-existent under the lateral move, albeit in mostly dry years. However the soil chloride under the lateral move system increased through about 80% of the sampled soil depths, indicating that long term salinity management must be considered under these systems if the leaching requirement is not being met.

Deep Drainage was investigated on a large number of sites using a simplified lysimeter design, the CRC also invested in the installation of a variable. Tension lysimeter at the Australian Cotton Research Institute in Narrabri. Dr Anthony Ringrose-Voase from the CSIRO used this lysimeter to compare direct measurements with alternative methods such as the barrel lysimeters used by Des and Thusitha, the chloride mass balance approach and commercial soil moisture probe methods.

Anthony was able to confirm that the barrel lysimeters and the variable tension lysimeter recorded similar patterns of deep drainage. The research showed that the drainage estimates provided by the chloride mass balance method were 60 per cent less than those measured by the variable tension lysimeter and confirmed the inappropriateness of using soil moisture sensing equipment to detect deep drainage below the root zone.



Dr Anthony Ringrose-Voase and Gupta Vadakattu inside CLW lysimeter.

Anthony was also able to differentiate between matrix and by-pass drainage. Matrix drainage was found to occur at very low rates (<0.5 mm/day) but could continue for periods of a month. In contrast, by-pass drainage was found to occur at higher rates of more than 3 mm/day as water flowed preferentially through soil cracks and macropores. This flow regime is more likely to occur when the soil surface layers (0 to 0.5 metres) are drier, which is often the case in early season irrigation events.

This research also suggests that matrix drainage is more efficient at leaching salt, which is an important consideration when viewed in light of the salt accumulation measured under the lateral move system in Des and Thusitha's work.

These findings from the CRC's deep drainage research have significant implications for irrigation management decisions aimed at minimising unnecessary deep drainage. Whilst rainfall can contribute significantly to overall deep drainage, good surface irrigation management is also clearly important in minimising these losses. It is highly likely that the improved surface irrigation practices widely adopted during the past decade will have significantly reduced deep drainage losses across the industry. The implications of deep drainage and leaching requirements on soil salinity under centre pivot and lateral move systems also requires consideration as the number of these systems has increased over recent years.

Efficient on-farm water storages

There are few irrigation schemes in cotton growing regions and most irrigators obtain water from a mix of regulated and unregulated rivers, streams and groundwater sources. To enable successful irrigation in this region, large on-farm storages have become widespread in order to capture water from irregular flow events and to retain farm runoff.

It is widely recognised that on-farm storages can be a major source of water loss on cotton farms. Previous studies in the Macintyre Valley indicated that storage losses ranged between 15% and 50%. Most of these losses were typically caused by evaporation. However, of the available technologies, those that were effective in preventing evaporation were cost prohibitive for irrigation storages and those that were inexpensive generally performed poorly. A cost effective evaporation solution was not available and development of such as solution was a priority for the cotton industry considering that on-farm storages are the major source of water loss on farm.

In response, the Cotton CRC assisted in a new collaborative approach, establishing a partnership with the Polymers CRC and the CRC for Irrigation Futures to develop new improved monolayer products and application systems to reduce these losses. Monolayers are chemicals which, when spread on the surface of a water storage, form a one molecule thick layer which acts to reduce the rate of water evaporation.

Unfortunately, existing monolayer products performed rather poorly. Further research by the Polymers CRC though, led to the development of a range of new generation monolayer materials which showed far superior evaporation and volatilization resistance compared to current commercial products. Provisional patents were lodged to protect the design philosophy for these new generation monolayers and further development of this technology and assessment of its commercial application is being progressed by the CRC Polymers.

Monolayer products are biodegradable and there is a need to reapply them frequently, but the advantage of these products is the low capital cost and the choice to apply them only when needed. They can best be managed using an application system that doses according to prevailing conditions.

Whilst the Polymers CRC developed new monolayer products, the CRC for Irrigation Futures (CRCIF) undertook complementary research into monolayer application systems and developed decision frameworks for determining optimum monolayer application strategies. However these technologies require an automatic detection system to advise on the condition of coverage so that appropriate dosing can be used. The Cotton CRC partnered with CRCIF to fund PhD student Paul Coop from the University of New England.

Paul tested a range of monolayer detection methods and novel techniques for reliability, robustness and potential for automation. He then developed a prototype floating wind assisted surface probe (WASP) which measures differences in water surface temperature to determine whether monolayer is present.

'Measurement of temperature, either with shallow depth thermocouples or surface IR thermometers, has shown to be the most reliable indication of the difference in evaporation rate which occurs with monolayer coverage. In the prototype WASP, these temperature changes are augmented by the application of artificial wind, and with measurements taking place in a confined, small volume of water' said Paul.

Measuring evaporation losses.

To complement this work in evaporation mitigation, the Cotton CRC also sought to improve industry understanding of the magnitude of both seepage and evaporation losses. As is the case in whole farm benchmarking, measurement is the first step for a grower to identify where water savings can be made. With the development of new measurement technology, able to determine and separate seepage and evaporation losses, the CRC saw an opportunity to promote this technology as well as collect industry wide benchmarks of storage performance.

In conjunction with National Water Commission the CRC aimed to measure seepage and evaporation losses from 136 storages. The project involved a novel design to also encourage the ongoing measurement of storage losses by engaging irrigation consultants to undertake measurements using the Irrimate™ Seepage and Evaporation Meter. By using cotton consultants, the project also aimed to build capacity within the industry to enable ongoing measurement once the project was completed.

It was found that 88% of storages (120 storages) had seepage of less than 4 mm/day, a rate which can be considered low. Whilst this is an excellent result for the industry, growers were reminded not to be complacent about the value of undertaking these measurements. Cotton Storages Project Manager, David Wigginton said

'When seepage is low, even a small error made by growers who estimate their losses can compound into a large volumetric discrepancy. One grower involved in the project used an estimate of seepage in his water budgets. Although his measured seepage was low at only 3 mm/day, his existing estimate of seepage was only 1 mm/day. This meant that his actual seepage was three times higher than he thought and his water budget was out by 50 ML per month'.

The project also obtained some complementary funding from the Healthy Headwaters Water Use Efficiency project, to investigate the value of water that could be saved by implementing storage structural solutions. These solutions include dividing a storage into cells or raising the height of the storage wall (and decommissioning a second storage). Water is saved in these scenarios by reducing the area over which a given volume of water can be stored, thus reducing seepage and evaporation losses.

Using an existing on-line tool (the Evaporation and Seepage Ready Reckoner) and the seepage and evaporation measurements that had already been obtained by the project, the cost of these strategies was determined in terms of the typical annual water savings. The cost effectiveness of both strategies was found to vary considerably depending upon the storage characteristics and the typical water holding pattern. The cost of water saved varied from $15/ML/year to $350/ML/year, with most of the results comparing favourably to the value of water on the temporary market.

New options for irrigation systems

Furrow irrigation is the main irrigation system used within the Australian cotton industry, accounting for over 80% of the total irrigated area. Whilst some growers use centre pivot, lateral move and drip irrigation systems with great success, furrow irrigation will remain a significant part of the industry for the foreseeable future. This is because cotton farms have highly variable water supply. For example during the recent drought, the area planted to cotton declined from 430 000 ha in 2001-02, to less than 60 000 hectares in 2007/08. As highly capital intensive pressurised irrigation systems must be used regularly to ensure they are cost effective, lower capital cost furrow irrigation fields provide the flexibility to respond to seasonal conditions.

This is not to say that furrow irrigation systems cannot perform just as well as their flashy cousins. In-field evaluations of furrow irrigation have shown that application efficiencies in excess of 90% can be achieved when irrigation management is optimised. In fact any irrigation system is only as good as the way in which it is managed.

However, surface irrigation does typically require more labour than the alternative irrigation systems, and labour has become very difficult to obtain in many cotton regions, particularly as gas and mining development has increased. Automated surface irrigation with adaptive real time control has the potential to optimise the performance of every irrigation event whilst simultaneously reducing the amount of labour required. University of Southern Queensland PhD student, Richard Koech is developing and field testing such a system.

The automation system developed by Richard can be controlled so that optimum irrigation management is implemented. This is a huge breakthrough for surface irrigation performance, as entire irrigation events can be optimised and managed with minimal human intervention.

Richard said, *'The system has been shown to be robust, reliable and provides the preferred management option in sufficient time to allow effective control of the irrigation events. The system was also successful in delivering irrigation performance significantly better than that achieved by the growers.'*

Optimising irrigation strategies

The cotton industry also has a long history of improving water use performance through improved breeding and agronomy. In fact respected industry researcher Dr Greg Constable has estimated that around half of the historical water use performance gains have come from improvements in this area.

The widespread adoption of Bollgard II® cotton throughout the industry has ensured that the CRC has continued important research into how cotton plants respond to irrigation at a physiological level. When the CRC started, it was predicted that these new transgenic varieties would have different characteristics such as high boll retention and higher yield potential which would have significant implications for the irrigation management of cotton. It was therefore important to investigate how these varieties respond to water stress and develop appropriate irrigation strategies.

Dr Steve Yeates (CSIRO) investigated the irrigation response of Bollgard II® cotton compared with conventional cotton varieties. His research confirmed the importance of minimising stress late in flowering with Bollgard II® as the yield loss per day of stress are double those encountered with conventional varieties at the same growth stage. Furthermore, the water use efficiency of Bollgard II® could be further improved by changing irrigation scheduling to account for a higher, earlier boll load associated with the increased insect protection provided by the transgenic traits.

Similarly, PhD student Marcelo Paytas from the University of Queensland clearly demonstrated the importance of maintaining adequate soil water early in the growth of high retention cotton. Even modest early water deficits can significantly affect yield and lint quality because this period is critical for high retention cotton to increase the supply of assimilates available for the use of post flowering. Marcelo also demonstrated that in the presence of moderate insect damage, Bollgard II® cotton uses less water than conventional cotton because conventional varieties have to grow longer to compensate for damage.

This work was able to be immediately implemented by cotton growers who aimed to avoid moisture stress during flowering and to schedule irrigations at smaller deficits than commonly used for conventional cotton. The application of these strategies by growers can help to explain how high productivity levels have been achieved despite low availability of water in many districts during the life of the Cotton CRC.

> ‘When insect damage to conventional cotton varieties is moderate to high, which is common in Australia, BollgardII varieties mature earlier and seasonal water use may be around 10% lower. But where insect damage to both varieties is low, there is little difference in water use between these varieties, with perhaps a slight favouring of the conventional varieties where only terminal damage occurred.’
>
> Dr Steve Yeates - CSIRO

Plant stress response can vary with atmospheric conditions, even when the soil moisture deficit does not change.

Irrigation strategies also became increasingly important in light of the severe drought that gripped the cotton industry for much of the life of the CRC. During this period many growers had no water for irrigation and almost all others were extremely water limited. These conditions required a greater focus on understanding the various irrigation strategy options required when water is extremely limited.

Dr Rose Brodrick from CSIRO examined the use of 'dynamic deficits'. Rose has identified how the plant stress response can vary with atmospheric conditions, even when the soil moisture deficit does not change. This means that it might be best to delay irrigations or bring them forward by measuring the current atmospheric conditions and using this data in conjunction with the soil moisture data which is commonly used within the industry. In a jointly funded PhD project supported by the Cotton CRC and Irrigation futures CRC Warren Conaty evaluated BIOTIC (Biologically Identified Optimal Temperature Interactive Console) which utilises infrared thermometers providing continuous measurements of canopy temperature to capture plant stress associated with different irrigation strategies. The work from both these projects offers the potential to improve irrigation decisions by allowing for plant stress, as indicated by crop temperature changes, soil moisture status and forecast weather.

The CRC's water research has investigated a wide range of related issues to improve water use performance across the whole farm. This research has contributed considerably to substantial improvements in water performance over the life of the CRC as the level of knowledge within the industry has been increased. Importantly, many of the CRC investments are set to return significant benefits in future years.

Tropical Northern Australia

– The Burdekin Region

Building on from the work undertaken by the Australian Cotton CRC investigating opportunities for cotton production in the Ord WA, this CRC focussed on developing a cotton farming system for the dry tropics in Queensland. At the start of this CRC, the potential to expand into Western Australia was limited due to the State Government's moratorium on GM crops and the lack of suitable cotton infrastructure in the region. By contrast, the Burdekin area in North Queensland offered greater possibilities since transgenic cotton was already grown in the state, it was closer to cotton processing infrastructure and cotton had the potential to be easily included in the sugar cane farming system as a highly profitable rotation.

The Burdekin however is climatically different to the Ord and consequently much of the work undertaken in the previous CRC was not directly transferable to this region. Unlike the Ord, the Burdekin (tropical Australia's largest irrigation area) has a climate and cropping system which is unique for cotton production in Australia due to the seasonal constraints that necessitate cotton to be grown in the wet season. In others regions, cotton is typically grown in hot dry summers where ideally crop water can be regulated via irrigation. Growing cotton during the wet season requires a completely different regime of crop management and brings with it many different challenges which were unknown at the time. Grower interest in this region was driven by both local sugar growers wishing to diversify and include a high value rotation into their sugar system as well as southern cotton growers looking to drought-proof their businesses.

A major output of the CRC in 2007 was 'NORpak-Ord River' which synthesised 10 years of rigorous scientific research involving the CRC and its partners into a rational blue print for sustainable cotton production in the region. NORpak-Ord River also confronted the GM debate by demonstrating the merits of GM as part of a production system, with reduced environmental footprint compared with the old non-GM system. Recent commercial scale validations proved that farmers, with little cotton experience, could produce high yielding cotton using NORpak. This experience combined with a more favourable political environment and cotton prices is the basis for significant planned commercial plantings in the Ord.

Former CEO Guy Roth CRC Chair, David Anthony, Western Australia's Chief Scientist, Professor Lyn Beazley, Geoff Strickland, Stephen Yeates.

Dr Stephen Yeates and Dr Paul Grundy.

In 2007, field experiments commenced in the lower Burdekin irrigation area lead by researchers Dr Paul Grundy (DAFF Queensland) and Steve Yeates (CSIRO). This initial research focused on:

1) Identifying climatic constraints for cotton production in the Burdekin and developing a set of practices that allow for the types of climatic and environmental risks that exist in this region
2) Determining the compatibility and synergies of cotton with the existing sugar / grains farming system.

Paul Grundy said the key focus of the Burdekin research was to determine the feasibility of cotton production with the prospect of wetter than average conditions.

Work with local growers rapidly demonstrated the limitations that periods of low sunshine and high humidity could have on the reproductive growth of cotton. The work also developed and tested novel management practices that could minimise identified constraints under these conditions.

A key concern was how the likely loss of fruit and flowers in response to cloudy wet weather during the wet season would affect later crop yield potential. Yet rather than being a negative, research demonstrated that wet season fruit losses due to shedding could be a beneficial adaptive response by the cotton plant. Shedding would have a limited impact on crop yield providing the crop was managed to ensure later compensatory fruit set when sunny conditions returned.

A key focus of the Burdekin research has been to understand crop and climatic interactions. DAFF Queenslandproject technicians collect crop sunlight interception data.

'Given these crop responses and climatic constraints agronomy needed to be tailored to maximise plant response for when the weather turns sunny at the end of the wet season' said Paul.

Best management practices were developed collectively ensuring the maximisation of compensatory yield production when sunny conditions returned in autumn, allowing for successful early winter picking. These practices included identification of the best sowing date and variety, management tactics for nitrogen, water, insects, crop trimming and the use of growth regulators.

Crop trimming is an innovation in which early season crops have the terminal shoot mechanically cut off delaying the onset of crop flowering and encouraging the plant to grow an open "vase" shaped canopy which subsequently increases light interception. The resultant delay in flowering from the trimming provides growers with an additional three weeks to conduct important growth stage dependent operations such as side dressing nitrogen prior to the onset of flowering which can be disrupted due to intermittent wet weather and impeded field trafficability.

Crop “trimming” whereby the terminal growing shoot of a vegetative stage crop is cut off is a useful wet season risk mitigation technique for growers in the Burdekin.

Showing Burdekin growers how cotton plants can be managed to minimise the impacts of high humidity and cloud during reproductive development.

Rapid adoption of a range of practices arising from the CRC research program has already stabilised yields for farmers trialling cotton in the region. Improved nitrogen fertiliser management as a result of this research has significantly increased fertiliser uptake efficiency from 30% to as high as 70%, which is a positive for the environment. Measuring the impacts cotton has on subsequent sugar crops has commenced and will continue beyond the life of the CRC.

'This work shows that there is real potential for the industry to develop in this region and adapt to any climatic changes that the industry may face', said Paul.

With the impacts of wet weather on crop physiology being a key research question, field work conducted daily regardless of weather conditions. Paul Grundy downloads a weather station in preparation for an approaching cyclone the following day.



Soils And Nutrition
- Lifeblood Of Our Cropping Systems

Soil health and nutrition are key to achieving high cotton productivity. Their management ensures the continued high productivity and quality which is a feature of Australian cotton production. These areas were a key focus in the Cotton CRC, with the aim of developing systems that improve the management of cotton plants to ensure profitable production and enhanced stewardship of the soil.

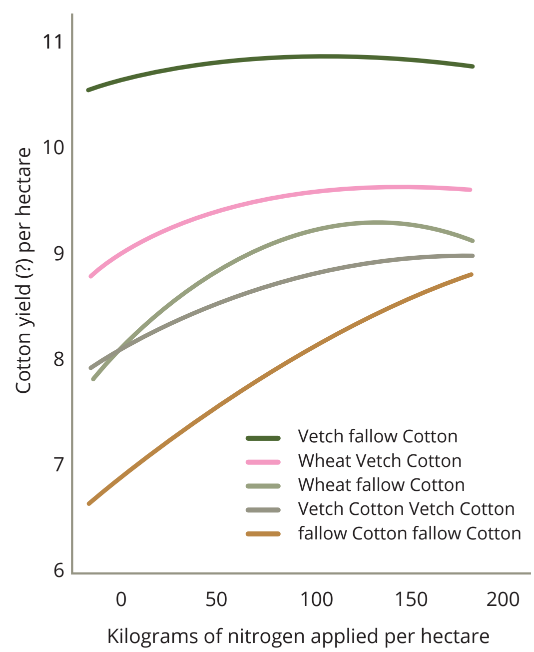
Early in the life of the Cotton CRC grower surveys and strategic planning meetings indicated that growers saw soil fertility and crop nutrition as a high priority for research. Growers realised that soil fertility could be improved and fertilisers applied to avoid nutrient deficiencies that could limit cotton production. Also at this time, the cost of fertilisers was increasing, and the industry was becoming more aware that cotton production may be contributing to excessive greenhouse gas emissions. There was a clear need for research to understand and improve the efficiency of nutrient use by cotton while reducing the environmental impact of cotton production through minimising greenhouse gas emissions.

The Cotton CRC initiated projects to address these issues. Research conducted by Dr Ian Rochester (CSIRO) demonstrated that very high yields (14 bales/ha) were achievable where legume-base cropping rotations with cotton were used. These rotations were also more able to sequester carbon into cotton-growing soils. The inclusion of legumes into the cropping system with cotton significantly improved soil health through better soil tilth, reduced soil strength, enhanced nutrient availability and slightly acidified soil; those characteristics provide a better environment for root growth.

'Vetch is an autumn–winter–spring growing legume crop recognised for its ability to grow rapidly in cold weather and fix significant amounts of nitrogen'.

'Our research compared vetch in a cotton rotation with other legumes commonly used in rotation with cotton, including faba beans, field peas, clovers and medics. Vetch's ability to fix nitrogen far exceeded all the other legumes, commonly fixing up to 200 kilograms of nitrogen per hectare and increasing cotton yield by 15%', said Ian.

Figure 2 Cotton yields obtained in differing crop rotations



Source Dr ian Rochester

Figure 2 shows the higher yields obtained when vetch was used in various cotton rotations. Note the greater need for nitrogen fertiliser with the continuous cotton and wheat rotation systems, especially where vetch was not grown.

Dr Ian Rochester taking soil cores to sample N level.

Dr Rochester also developed a user-friendly method to identify nitrogen fertiliser use-efficiency (NUE). For cotton that receives the economic optimal amount of nitrogen fertiliser, NUE averages 12.5 kilograms of lint per kilogram of crop nitrogen uptake. Surveys of on-farm NUE showed high crop nitrogen uptake with moderate yields at many sites, indicating poor NUE. This suggested that many growers currently use more nitrogen fertiliser than is required, and a reduction of 25% in N fertiliser inputs was unlikely to impact negatively on cotton production. More recently, Dr Ian Rochester developed a new test that assesses nitrogen fertiliser use efficiency by analysing the nitrogen content of the fuzzy seed as it is produced at the cotton gin.

Dr Ian Rochester's research also contributes to the CRC's decision support system for cotton nutrition, NutriLOGIC. The NutriLOGIC program allows growers to enter their soil and plant analysis data and the user is advised on the nutrient status of the soil or crop and remedial action if required.

Postgraduate student Meredith Errington.

Postgraduate student Meredith Errington, from the University of Sydney, investigated nutrient cycling in Bollgard® II cotton varieties to better understand their nutrient demand. She clearly demonstrated the relative ineffectiveness of foliar applications of nutrients in the Australian environment where hot, dry conditions create drought responses in the cotton leaves, limiting the penetration and incorporation of foliar applied nutrients. The usefulness of foliar application of nutrients to plants growing in soils with high natural fertility, such as the vertosols typical of the Australian cotton growing region, is also questionable. However, plants growing in deficient conditions, where nutrients are limiting to growth and root uptake of nutrients is insufficient for plant demand may show a greater uptake and yield and quality response to foliar applications of nutrients.

Soils are a complex of minerals, organic matter, water and air and are the lifeblood of our cropping systems. A major proportion (~75%) of Australian cotton is grown on Vertosols (Vertisols and Usterts), of which almost 80% are irrigated. Typically they have a self-mulching layer 2-5cm deep, overlying a zone of blocky peds to depths of 30-50cm. These soils have high clay contents and strong shrink swell capacities meaning they form deep soil cracks which close when wetting occurs due to the swelling of the soil, but are frequently sodic at depth and prone to deterioration in soil physical capacity if incorrectly managed.

Cotton growing in wheat stubble.

> 'The resiliency and sustainability of cotton farming systems are dependent upon a number of interacting factors which include climate, soil quality, plant nutrition, farm management, weed and disease incidence and economic factors. Frequently when external constraints such as drought and economic factors impose on farming systems, growers who manage their soils to optimise quality are able to respond more rapidly, thereby sustaining profits.'
>
> Dr Nilantha Hulugalle,
> Principal Research Scientist with NSW DPI

Dr Nilantha Hulugalle, NSW DPI soil research has focussed on the influence that grower management practices such as tillage, choice of crop rotation, irrigation, stubble management and the incorporation of soil amendments have on soil quality, carbon sequestration, greenhouse gas emissions and soil water storage. Soil research led by Dr Nilanth shows that soil organic carbon (SOC) in the 0-60cm depth ranges between 50 and 70t/Ha. Although legumes contribute large amounts of carbon to the soil, the carbon is not retained as residues undergo rapid microbial decomposition due to their low carbon to nitrogen (C/N) ratio. Carbon inputs of C4 crops such as sorghum and corn were much larger than those of C3 crops such as wheat. A major proportion of that carbon came from their root systems. Increasing water availability and reducing tillage improved root growth. Soil organic carbon sequestration rates were generally negative or neutral, except in the case where a stressed soil (disease, sodicity, salinity) was undergoing rehabilitation. Estimates of carbon inputs, based on above-ground and root dry matter, together with measured sequestration rates indicated that large losses of carbon were occurring, most likely due to a combination of accelerated erosion, runoff and microbial decomposition.

Nilantha Hulugalle has been involved in cotton research for 18 years, over which time he has demonstrated his commitment to the improved productivity and sustainability of the entire cotton industry whilst always taking a truly collaborative approach to his research.

Storage of SOC was positively related to dry matter inputs, average maximum temperature, soil aeration and water availability, but, was negatively associated with N fertiliser inputs.

Greenhouse gas emissions in cotton can be reduced through modifying farming practise. Eliminating inversion tillage, minimising use of groundwater, sowing winter crops in rotation with cotton, reducing/optimising mineral N fertiliser rates, and substituting a legume and therefore fixed N for mineral N fertiliser all reduce greenhouse gas emissions. Water losses through drainage could be reduced and soil water storage increased (i.e. water conservation improved) by including a wheat crop in the rotation with in situ stubble retention under less frequent irrigation. Management systems that conserve all rainfall received in situ, thereby reducing irrigation requirements can contribute greatly to the sustainability of irrigated cropping.

Measuring greenhouse gas.

Dr Oliver Knox (CSIRO) investigated the impact of Bollgard II® on soil biota in response to public concerns that the widespread use of genetically modified organisms could detrimentally affect soil biota. He confirmed that there are no consistent changes in soil ecology associated with the use of transgenic varieties. He also identified the potential for biological control agents (fungi and nematodes) for the control of soil pathogens. Again, more research is needed for industry outcomes to be realised.

Soil health also includes physical and chemical characteristics. John Bennett in his PhD research (USyd) showed that the amelioration of irrigated sodic soils with gypsum alone did not persist beyond 2.5 years post-gypsum application. However, the use of gypsum combined with chicken manure/wheat straw compost proved more effective than the use of gypsum alone as a result of better retention of calcium in the soil profile.

James Quilty in his PhD research on the effectiveness of seven organic amendments in improving soil health in irrigated cotton farming systems demonstrated the variability in responses achieved with these amendments. Positive responses on soil microbial biomass, soil organic carbon content, soil nitrogen content and soil aggregate stability were identified on some soil types for some amendments, but not for others. The effect on crop performance was also variable, with inconclusive effects for most organic amendments tested. Only seaweed extract and composted wheat straw and chicken manure benefited root growth for some crops on some soils. No products produced consistent effects on cotton fibre quality.

Full stops in the field installed (by Oliver Knox) to measure nitrate and ammonium in by pass irrigation water and also attempted to detect Cry proteins.

John Bennett, USYD talking to growers at a soil health day.

New tools and technologies

At the time the Cotton CRC was initiated, government policy for CRCs emphasised the importance of outcomes which could be commercialised by Australian industries, especially small-to-medium enterprises (SMEs). The Cotton CRC Commonwealth agreement included several specific outcomes that would have strong commercial application, should the centre be successful in these areas. Given the limited life span of a CRC, and that some of these outcomes may take many years to proceed to commercialisation, the Cotton CRC has proven to be highly successful in achieving many commercial outcomes.

'The Australian cotton industry has been built on a foundation of innovation, in practice and in technology. It is unique in our national agriculture in its close integration between end users and researchers, and its rapid adoption of new technology. CRC research projects have maintained that tradition, helping to ensure that cotton remains a leader in Australian agriculture,' Professor Peter Gregg, Chief Scientist for the CRC.

Magnet®, shown here by Professor Peter Gregg and Dr Alice Del Socorro, is is a blend of synthetic equivalents of naturally occurring plant volatile compounds which mimic nectar-rich flowering plants and are attractive to adult moths of *Helicoverpa* spp and several other pest species.

Novel approach to controlling pest species with attractant technology

'Magnet®', the world's first commercial attract-and-kill technology based on organic chemical compounds known as plant volatiles, was registered in 2009 by AgBiTech Pty. Ltd., representing the culmination of a decade of research led by Professor Peter Gregg and Dr Alice del Socorro (UNE), spanning all three of the cotton industry's Cooperative Research Centres.

Magnet® is a blend of synthetic equivalents of naturally occurring plant volatile compounds which mimic nectar-rich flowering plants and are attractive to adult moths of *Helicoverpa spp* and several other pest species.

Conventional approaches to developing attractants usually begin with identification of the primary host of the pest, with the assumption that even pests with a broad host range have an original primary host, and then identification of chemicals from that host that make it attractive to the pest. However this approach is challenging as the primary host is often hard to define. Further, the compounds involved in attraction may require extensive testing to satisfy regulatory requirements, especially around safety. The use of plant volatiles already approved for food use overcame the latter problem. The challenge was to isolate compounds that are attractive to *Helicoverpa*, from the large range potentially available. This was done using knowledge of the types of compounds from host plants that are attractive to the moths as a starting point to evaluate the attractiveness of a range of individual compounds and later blends of compounds in a two choice olfactometer.

Professor Peter Gregg said that Magnet can be applied to less than 2% of a farmer's crop in narrow strips, attracting moths to feed on the product which is laced with small quantities of insecticide. Controlling the moth stage results in up to a 90% reduction in eggs laid. The subsequent reduction in caterpillar numbers means less damage to crops and greatly reduced need for farmers to spray broad-acre insecticides.

Bollgard II® cotton also provides control of *Helicoverpa* spp. and its widespread adoption in the cotton industry significantly reduced the cotton market for Magnet®. This limited direct commercial application in Australian cotton due to the small percentage of the industry (less than 5%) growing non-transgenic cotton, and indeed Magnet® has been used on about half of this area. Other opportunities for application of Magnet are being developed overseas, including against *Heliothis virescens, Helicoverpa zea, Trichoplusia ni, Spodoptera frugiperda* and *Agrotis* species in the USA – all pests of cotton and other crops. The most promising application is against *Helicoverpa zea* in sweet corn. Magnet® is also effective against diamondback moth (*Plutella xylostella*) on brassica crops in Thailand where a similar product is registered as Chalice®.

Dr Robert Mensah

Plant-based insecticides for controlling pests and their behaviour

Based on an observation by prominent cotton farmer, Peter Glennie, NSW DPI researcher Dr Robert Mensah identified a plant on a collaborator's farm noting the low abundance of insects on it.

This led Dr Mensah to speculate that the plant might contain compounds with repellent or insecticidal properties, and they might be extracted for use in managing cotton pests - a extract that became known as 'Plant X'.

Plant X is a fractioned extract from a plant that demonstrates insecticidal activity and insect behaviour modification. The extract demonstrates efficacy on a wide range of insect pests such as *Helicoverpa* spp., green mirids, green vegetable bugs and whiteflies. Uniquely within the Cotton CRC, this project was co-funded by SME, Growth Agriculture. Operated by NSW DPI, in collaboration with other research organisations such as Southern Cross University, this project has now been fully transitioned to commercial partner, Innovate Ag (a joint venture of Growth Agriculture) and is progressing swiftly though registration processes which will allow sales of product to Australian and international farmers in the next three to five years. Innovate Ag has secured a grant of up to $1.5 m from Commercialisation Australia which will cover %50 of the eligible development costs for the next 2 years. This, with the continued support of local cotton growers will assist them bring the product to fruition.

Additional work in this area is a 'proof of concept' study of the use of cotton seed oil as part of a formulation for five different plant-based active ingredients from external partner, Native Fire Active Pty Ltd. Through collaborative work led by NSW DPI, the five different active ingredients were tested with cotton seed oil and one, Green Fire, provided commercial scale efficacy against a range of pest species. As a result, Native Fires Pty Ltd has commenced further registration and commercial activities with Green Fire.

farm program
chapter one

Cotton seed testing for nitrogen use optimisation

One of the key challenges with cotton nutrition decisions is having confidence that the crop has sufficient available nitrogen to achieve its yield potential while ensuring that it is not over-applied, which results in increase production costs, difficulties in crop management and nitrogen resources lost to the environment.

Collaborative work conducted by Cotton CRC and CSIRO researcher Dr Ian Rochester has shown that the use of near-red infrared (NIR) scanners with the correct correlation can be used to estimate quickly the nitrogen content of fuzzy seed (cotton seed which has had most of the lint removed). With the correct calibration, it is possible to quickly and economically measure cotton plant Nitrogen Use Efficiency (NUE) and, ultimately, determine if a crop has received ideal nitrogen resources. This technology can be used to measure the success of the crop's nutrition management strategy, potentially allowing ongoing adjustments to fine-tune the nutrition decision process.

New round module harvesting technology, coupled with processing data collected at the point of ginning, not only provides fibre quality information that can be linked back to specific regions in a field, it also provides an opportunity for seed nitrogen data to be collected. Should the cotton industry wish to proceed further with collecting and using this kind of information, the addition of an automated sampling system for seed nitrogen in the ginning process will quickly and accurately provide quality data for optimising nitrogen use in the industry.

Where it ends

The people and the research of 'The Farm' program have made significant contributions to the ongoing sustainability of the Australian cotton industry. Over the last seven years we have seen significant change in the industry ranging from the rapid uptake of GM technology, drought, emergence of secondary of pests and the development of climate change policy. One of the most significant contributions of this CRC in responding to these challenges has been broadening the focus of the industry from a field perspective to a larger landscape view. This new approach has lead to a better understanding of the ecological interactions at the farm and landscape scale. This broader understanding us allowed us to more effectively link the research of this program to the Catchment and Communities programs.

The Cotton CRC and the work emanating from The Farm Program ends at a time when the industry is bouncing back after a decade of drought. The recent floods have filled the dams and the forecast for the next few years looks promising. In 2012 we have seen the largest area of cotton planted meaning that there is likely to be sufficient resources to build on the work of 'The Farm' program.

While it is always sad to see the end of era in terms of collaborative CRC research, the future of cotton production related work for the industry is safe hands.

Jane Trindall

chapter two

catchment program

This report details the outcomes and impacts of the Catchment Program research, development and extension on rivers, groundwater, water quality, ecosystem services and partnerships. Several key factors of the Catchment Program together made for a tremendously effective recipe.

1. **Meaningful collaboration** The Cotton CRC has been in the unique position to effectively engage with irrigators, government decision makers, the community and other water users. This alone has given the Cotton CRC a greater capacity and ability to achieve outcomes from its research in cotton catchments.
2. **The best researchers** We have worked with locally based environmental researchers who have embraced working within an agricultural industry.
3. **Important science** The focus on issues meaningful to the cotton industry and the catchments where it is grown made the science readily useable and easily adopted.
4. **Useful tools** Packaging results into innovative tools, products and delivery mechanisms including books, calendars, *my*BMP, workshops, field days and forums has broadened our reach and maximised our impact.
5. **Research capacity** Eighteen PhDs have been carried out in the Catchment Program, illustrating the vital contribution the program has made to build the research capacity of ecologists, chemists and hydro-geologists, and the knowledge of natural resource in the northern Murray Darling and Fitzroy Basins.

The Cotton CRC was able to provide local science, with local partners for local issues. The crucial link of coordination, by bringing partners together across multiple disciplines to extend their reach and build capacity was the real success of the CRC.

Catchment Program Leaders

Dallas Gibb	2005 – 2006
Dr Paula Jones	2006 – 2009
Jane Trindall (nee Macfarlane)	2009 – 2012

Jane Trindall

The background

The Cotton Catchment Communities CRC predecessor, the Australian Cotton CRC (1999-2005), had placed increasing emphasis on the environmental performance of the cotton industry. In partnership with the Cotton Research and Development Corporation (CRDC) and Land and Water Australia, it had released *Guidelines: Managing riparian lands in the cotton industry in 2003* which was widely supported by cotton growers. It had also initiated a number of environmental research projects which provided a sound platform for the Catchment Program. These included the *Review of Biodiversity Research in the Australian Cotton Industry* (Reid, O'Shea and Silberbauer, 2003) and the second workshop of the Northern Murray-Darling Water Balance Group held in 2003, which mapped out future directions of deep drainage research in the northern Murray-Darling Basin. Most of these projects were externally funded. The success of the Cotton Catchment Communities CRC rebid gave this CRC and its affiliates the scope to drive environmental research in the direction most relevant to cotton growers, farms and cotton growing regions.

Still, there were major external drivers for including the Catchment Program in the current CRC. Federal and State government environmental policy had been gaining profile and rapidly evolving throughout the Nineties and into the new millennium. In December 2002, the Prime Minister identified 'an environmentally sustainable Australia' as one of four National Research Priorities, and water utilisation and biodiversity management as key goals within this research priority. In 2005, when this CRC began, Catchment Management Authorities (CMAs) and Natural Resource Management (NRM) bodies had just been established. There was extensive interest from CMAs and NRM Bodies as they were developing their Catchment Action Plans and were looking for science to underpin their decisions. Given the rapidity with which governments were moving in relation to environmental reforms in water and vegetation, there was a need for up-to-date advice to underpin the implementation of legislation, policies and plans at all levels of government.

At the same time, a large debate was going on regarding native vegetation, water reforms, groundwater and surface and groundwater connectivity. Like other broad-acre agricultural industries, the cotton industry has had a significant impact on biodiversity, occupying large areas of once naturally vegetated landscapes and diverting a significant amount of surface water and groundwater resources in cotton growing regions to irrigated cotton production. The replacement of native vegetation, regulation and diversion of river flows and extraction of ground water has reduced the extent or impaired the health of natural ecosystems and reduced the habitat of many native organisms. Paradoxically, large tracts of natural floodplains, wetland habitats and native vegetation remain on cotton farms and it was perceived, with further R&D, that cotton growing operations could be managed in ways that further increase profits and the value of these habitats for biodiversity and other ecosystem services. There was an increasing expectation that all agricultural industries operating in Australia would do so in an environmentally sustainable manner. The cotton industry needed to demonstrate that it is a responsible environmental manager and could take the lead among the agricultural industries in setting and achieving targets in cotton growing areas and for the ecosystems and environmental services that underpin or are most heavily affected by the industry. Former CEO, Guy Roth reflects, *'at the time natural resource management was very important in the eyes of the community and stakeholders and it was a good opportunity for the cotton industry to show leadership and address natural resource management issues relevant to cotton farms.'*

The Catchment Program pledged *"Best practice cotton enterprises delivering sustainable ecosystems and reduced impacts on catchments."* And in doing so the program tackled environmental research, development and extension at two scales – catchment and on-farm.

From its inception the Catchment Program fostered collaborative research with applied outcomes through partnerships between researchers, industry, end users and government departments. This approach ensured the program identified and focussed on issues most meaningful to the cotton industry, and gave environmental research a fresh lens through which to recast conceptual models and engage with growers. The Catchment Program has enjoyed partnerships with over 50 organisations who have invested nearly $7 million of external investment into this program (at least double the $2.4 million invested by DIISR). This chapter outlines the objectives, and details the outcomes and impacts of the sub-programs undertaken by the Catchment Program.

Sub-programs	Outcomes
1. Rivers	Knowledge to underpin the integrated management of river flows to ensure profitable irrigation industries and sustainable ecological condition of floodplain ecosystems.
2. Groundwater	An improved understanding of the current condition of groundwater systems in cotton catchments and the demonstration of best practice scientific approaches for determining sustainable groundwater yields.
3. Water Quality	Establish baselines for on-farm water quality and develop remediation processes with the capacity to deliver both farm and catchment benefits.
4. Ecosystem Services	Best-practice guidelines for managing terrestrial biodiversity and ecosystem services on farms enabling growers to sustain production and increase profits and assisting catchment bodies achieve catchment targets.
5. Partnerships	Development of science-based information resources for cotton growers and catchment bodies which promote well informed, best practice natural resource management decisions and activities in cotton catchments.

catchment program
chapter two

Rivers and wetlands

The cotton industry is located along the riverine areas, floodplains and wetlands associated with the major inland rivers of the northern Murray Darling and Fitzroy Basins. 90% of the nation's cotton comes from the northern Murray Darling Basin (the Darling system). Compared to the southern Basin (the Murray system), the northern Basin is hotter, has higher evaporation, less predictable flow, and more frequent and longer periods of very low flow. Rivers are mostly unregulated and experience large flood events in response to summer rainfall events in upper catchments. These floodplain landforms are the most extensive, fertile and productive croplands in the country. However, they are also among the most extensively and intensively farmed, and the ecosystems and flora and fauna they support are among the most threatened and least conserved in the national reserve system. For example, the nationally endangered Coolibah - Black Box Woodlands can be found on many cotton farms.

Cotton growers are therefore in a unique position to influence the conservation of some of Australia's most endangered ecosystems and species, and they can also significantly impact on the environmental wellbeing of the entire Murray Darling system. Since environmental flow allocations were implemented almost two decades ago, the need for science to underpin these decisions has become more and more obvious. 'There was a natural fit in developing and understanding the science in water management and biodiversity which were linked in terms of the riparian zone' the first Catchment Program Leader Dallas Gibb recalls. A key goal of this research was the integrated management of river flows to ensure profitable irrigation industries and the sustainability of flood-plain and river ecosystems. To accomplish this goal, research projects were initiated in four of the major catchments in the northern Basin - the Condamine-Balonne, Border-Rivers, Gwydir and Namoi.

"The cotton industry is located, all along the major rivers of the northern Murray Darling Basin. These floodplains are the most productive part of the catchment in terms of fertile soils for cropping and where the environment is critical in terms of billabongs, wetlands, and majestic river red gums."
Former Cotton Catchment Communities CEO, Guy Roth 2012.

JS Photography

Floodplain Ecology

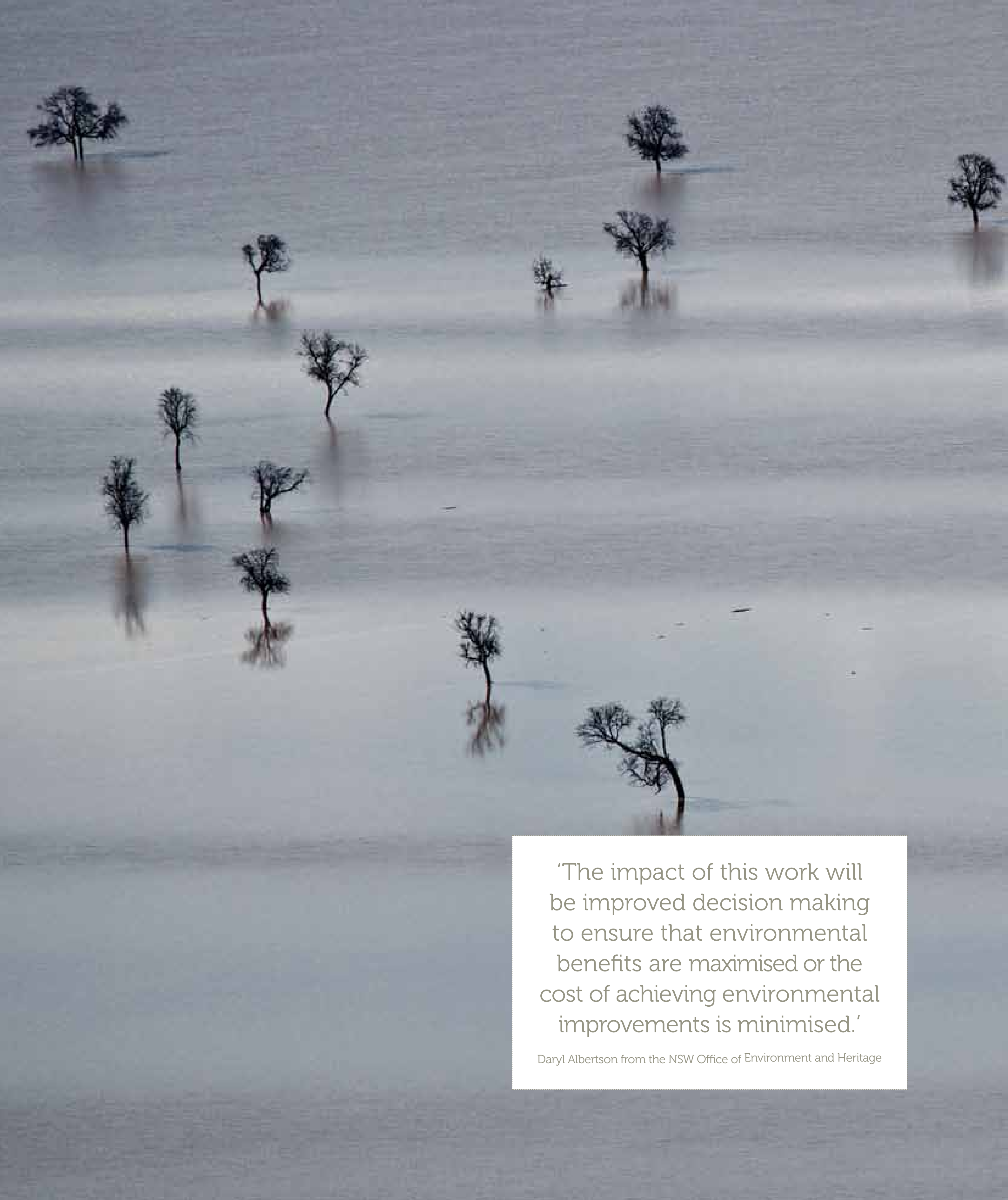
In 2005, the Cotton CRC formed a major partnership in this sub-program with Land and Water Australia and the University of New England (UNE) to investigate environmental flows in the Lower Gwydir. The Lower Gwydir floodplain has terminal wetlands of international importance for bird breeding and is recognised on the international Ramsar Convention of Wetlands and is therefore of significant conservation value. Research, led by Dr Glenn Wilson (UNE) and involving post-doctoral research fellow, Dr Tobias Bickel and PhD student Dr Peter Berney, examined the ecological responses of in-stream and floodplain environments to high and low water flows in the Lower Gwydir system. Responses by fish species were observed, and the effects of inundation on terrestrial vegetation communities were examined alongside the effects of grazing. Dr Glenn Wilson says

'This study was one of the first overarching analyses of ecological responses in the Gwydir.'

Gwydir environmental contingency allowance (ECA) managers continue to use findings of this project, which provide a greater understanding of how aquatic ecosystem components respond to flow variability. The study found longitudinal variation in structural habitat (or its modification of hydrological influence) appeared to be critical in shaping fish assemblages. The relationships between recent discharge and fish abundance varied considerably, although there was evidence for maximized recruitment under intermediate discharge levels at the pulse and seasonal scales. Out of the rivers and into the wetlands, it was discovered the altered hydrological regime in the Gwydir Wetlands facilitates the dominance of *Phyla canescens* rather than this species being competitively superior to *Paspalum distichum* suppressing its growth.

Wetlands are transformed as the plant community responds to flooding. These allow a comparison of changes in plant communities between grazed and ungrazed sites.

Key findings indicate factors likely to improve the effectiveness of ECA releases include: timing environmental water releases to coincide with the growing season of native species; excluding grazing immediately after environmental flows to allow optimal vegetation growth; and 'piggy-backing' ECA flows onto natural flow events to maximize the duration of wetland inundation. This allows ECA managers to make more effective decisions on volume timing, duration and depth in order to maintain wetland conditions and associated ecological processes. Major findings of this research have been incorporated into NSW wetlands grazing guidelines, the NSW Wetland Recovery Program, and management advice to the Australian Government and Murray-Darling Basin Authority.



'The impact of this work will be improved decision making to ensure that environmental benefits are maximised or the cost of achieving environmental improvements is minimised.'

Daryl Albertson from the NSW Office of Environment and Heritage

CASE STUDY

The Lower Gwydir Wetlands

The Lower Gwydir wetlands are an inland terminal delta of the northern Murray-Darling Basin, spanning more than 100,000ha. They are historically significant for vast rookeries of cormorants, ibis, spoonbills, egrets and herons. The largest documented breeding event was in 1998 when 150,000-183,000 breeding pairs of straw necked ibis were recorded. The Cotton CRC investigated the surface flows and ecology of streams and wetlands in the lower Gwydir.

Key research findings:

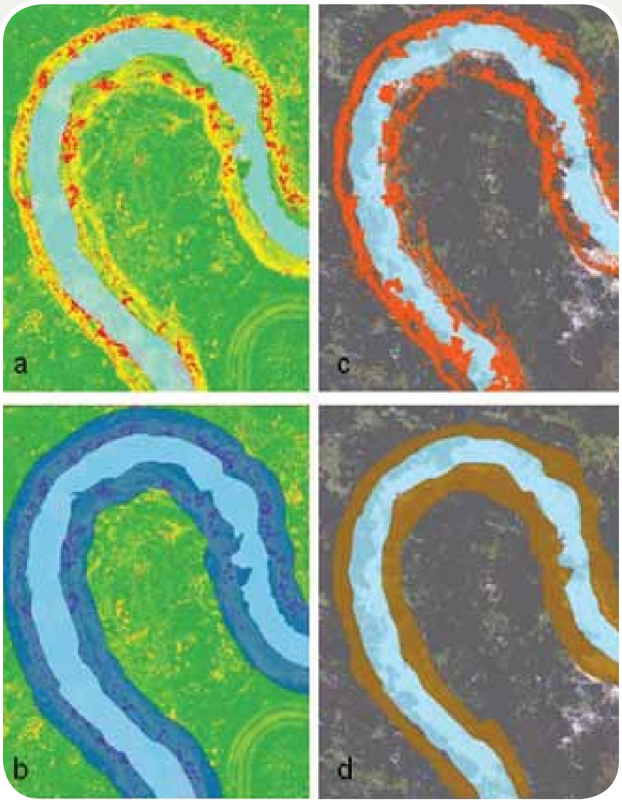
- Inundation drives the plant communities of these wetlands. Wetter sites surveyed had the highest numbers of perennial species and lowest numbers of weeds including lippia.
- Impacts of grazing exclusion differed markedly amongst plant communities and were not particularly consistent over time.
- An important impact of altered inundation regimes in floodplain wetlands is the effect of prolonged dry periods on the competitive interactions between native species and introduced species such as lippia.

University of New England researchers undertaking fish sampling in the Gwydir River. PHOTO TOBIAS BICKEL

What does this mean?

- This project illustrated the close links between the water regime in floodplain wetlands and the composition of the plant communities. It demonstrated how soil moisture levels affect both competitive interactions at the individual plant level, and at a broader scale, the responses of the plant communities to disturbances such as grazing. As a result of the research managers can develop hypotheses about plant community responses to particular water regimes and to land use changes such as exclusion of domestic grazing, which can be tested in the adaptive management approach now being adopted by wetland managers in major wetland systems in the Murray Darling Basin.
- Fish recruitment responses were observed in relation to individual Environmental Contingency Allowance (ECA) events, but establishing relationships between discharge and juvenile fish abundance was more complex.

LiDAR data was found to be a useful tool for understanding river processes at reach scales in the Namoi. 3D riverine habitat maps can be developed and linked to river flow information. Understanding the spatial distribution of riverine habitats and their link to river inundation provides a detailed quantitative means of optimising river flow delivery regimes whether for consumptive or environmental purposed to maximise environmental outcomes.



Also in the Gwydir, an inundation and vegetation response model (IVRM) was developed for water management by applying a conceptual understanding of the flooding patterns and vegetation response of large floodplain wetlands. This conceptual node – network approach, though developed in relation to the Gwydir wetland systems, is applicable to a range of floodplain wetland systems. Sue Powell completed this PhD with support from the Australian National University (ANU), CSIRO Water for a Healthy Country and the CRC. Sue's work has been used to inform the development of a decision-support tool – the DSS IBIS by the ANU and the NSW Office of Environment and Heritage. The tool is designed to guide environmental flow decisions in the Gwydir. It was used by the Australian Government Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) in the development of the report to the Environmental Water Holder on the valley scale delivery of environmental water in the Gwydir.

Further south, in the western reaches of the Namoi catchment, an analysis of tree size distributions in coolibah remnant woodlands and dense regeneration revealed that, dense regeneration occurs where large trees are sparse and conversely, few or no coolibah seedlings are found in remnant woodlands where mature tree density is higher than 22 stems per ha. Results from UNE PhD student Megan Good indicate that dense coolibah regeneration is a vital part of the coolibah life-cycle which occurs only under very specific conditions.

A series of projects set about documenting riparian and wetland vegetation type and condition in the Namoi Catchment. In partnership with the Namoi CMA, Ecological Australia and GHD produced three key outputs:

- A riparian vegetation condition assessment in the Namoi valley which provides baseline information for future monitoring in riparian health.
- A new framework for the development of a riparian assessment index specifically designed for use by the Namoi CMA.
- Development of a 3D inundation model by applying medium resolution wetland inundation mapping techniques to a reach of the Namoi River.

Dr Bronwyn Witts, from the Namoi CMA, says these projects have *'...given us baseline data as well as better understanding of the natural systems. These projects have contributed to drafting of the new Catchment Action Plan and achieving riparian vegetation condition targets in the Namoi.'*

The field crew at Weir River, Talwood. From left: Laurisse Frampton, Samantha Capon, Andrea Prior (seated), Aaron Nix, Jacqui Lee and Rob Rolls.

As we know, during the term of the Cotton CRC, the drought in eastern Australia became the worst drought on record (1999-2009) only to be broken by flooding rains across in Central Queensland and the Northern Murray Darling Basin in 2011 and 2012. Up until 2011 all research in this sub-program occurred in the height of the drought, with investigations centring around 'low – no' flow conditions. In 2011/12, a partnership with the NSW Office of Water, and the Queensland Department of Environment and Resource Management and Griffith University presented an opportunity to investigate the regeneration of floodplain vegetation in response to large -scale flooding in the Condamine -Balonne and Border Rivers. The aim was to provide key ecological information necessary to monitor and review the NSW Water Sharing Plans, Queensland Resource Operation Plans and contribute to the implementation of the Integrated Environmental Flows Monitoring Program proposed under the NSW / Qld Intergovernmental Agreement for the Border Rivers and Intersecting Streams. Project leader, Dr Samantha Capon (Griffith University) says *'A major finding of this project is that the substantial flooding that occurred in the study sites in early 2011 has not been followed by a significant (sexual) recruitment event of key riparian eucalypt species, i.e. river red gum and coolibah. This suggests that a suite of criteria need to be met for successful seedling establishment amongst these species in this region in addition to flooding.'*

> 'Our river and wetland research has been, or is being used, by government agencies in at least four catchments in the Northern Murray Darling - the Condamine-Balonne, Border-Rivers, Gwydir and Namoi. It is likely that the key findings are already contributing to the improved natural resource condition in these catchments'.
>
> (Catchment Program survey 2011)

When we look at these results of all of the floodplain ecology studies undertaken during the CRC across several catchments in the northern Basin we can observe some fascinating trends. The pivotal role of water in these natural floodplain environments is highlighted. However, equally as important are the conditions and management regimes which are required for triggering floodplain vegetation species responses and enabling these communities and species to persist in these landscapes. Dr Samantha Capon says

'The implications of these findings are that the criteria for successful establishment of seedlings of key riparian eucalypts in the northern Basin are far more complex than merely 'just add water' as might have previously been assumed from observations in the southern Basin and that good overbank flooding will not necessarily result in riparian vegetation regeneration, at least amongst these asset species.'

personal profile

Sue Powell

Sue Powell describes her career of grappling the social and environmental complexities of wetland research as a 'long-term vision' for protecting the future of Australia.

A Canberra-born girl, Sue's work began as a young woman who found herself involved in ground and surface water research, which in turn set a course that's since taken her across the state of NSW and back to Canberra, with various research organisations.

In 2007, as a mature aged student, Sue embarked upon a PHD - with the Integrated Catchment Assessment Management Centre (iCAM) at the Australian National University (ANU) - only to be hit mid-way with an unexpected and traumatic sports injury that resulted in long-term nerve damage and the loss of feeling in one of her legs.

As an active and independent woman – it was a big hurdle to tackle. But Sue has taken the proverbial bit between her teeth, and amongst getting back on track with her PhD, has since won three out of four World Championship para-cyling events – and is headed to the London Paralympics later in 2012.

"I've always appreciated the expression that 'life's a journey, not a destination', she said, "and it's honestly that same passion that I feel about the future of Australia's environment."

"The whole issue of environment is an enormous and political topic, and what we (researchers) do isn't often an instant in-your-face result, it's years of plodding away in the background with a big picture focus," she said.

And that requires tenacity.

She jokingly refers to the fact that she often has to *"put on her Greenie hat," but that it's all aimed at doing the best for the farmers and the immense topic that is 'water'.*

Sue says that the Cotton CRC has been a "fantastic" supporter of her research work, and that in terms of the very future of the cotton farming community – such support has been vital.

"It was actually the CRC that encouraged me to pursue a thesis and a PhD in the first place," she said.

She'd been working on her Master's Degree in Environmental Sciences in 2004, and this had included being involved in researching the Gwydir Wetlands using remote sensing to see how vegetation response and flooding worked.

Sue successfully completed her PhD in 2011.

Coming up is a chance for Sue to pursue work with evidence-based-analysis between river flows and the MDBA.

"This will then become the chance to do ongoing research on the mix between ecological response and water allocation/planning," she said.

"It's very encouraging to see that the balance between production and environmental decisions are becoming more integrated; thanks to the implementation of programs such as myBMP and IPM."

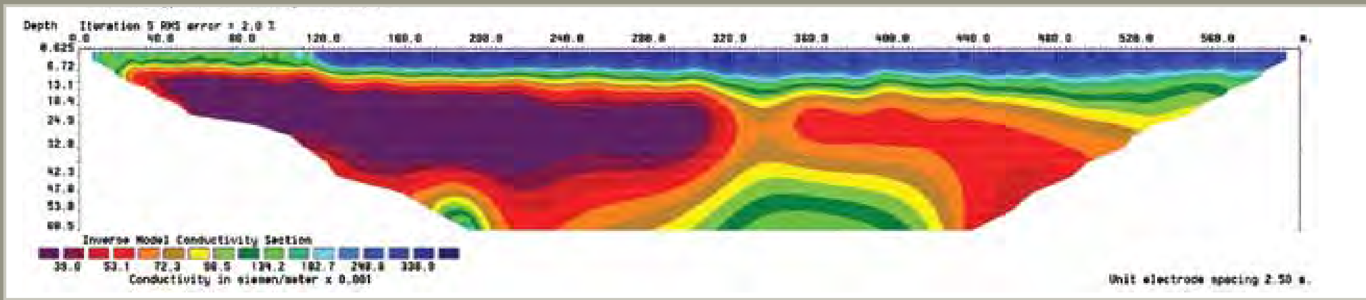
Olive Perchlet
Ambassis agassizii

Golden Perch
Macquaria ambigua

Fish

As almost all cotton enterprises, particularly irrigated cotton, have rivers and wetlands on and alongside their farms, cotton growers have the potential to impact and improve fish habitat on farms and in rivers. To examine the possibilities here, Dr Susan Lutton from the Australian Rivers Institute at Griffith University began her PhD on "Aquatic biodiversity and the ecological value of on-farm storages on irrigation farms". Despite the difficulty of undertaking her research during a drought, one of Dr Lutton's key findings was that, contrary to many models, irrigation storages are valuable to aquatic biodiversity. They can in fact have far fewer exotic species than natural wetlands.

At the end of 2009, in partnership with the Namoi CMA, Murray Darling Basin Authority and NSW Department of Primary Industries a project commenced to test and refine ways of screening fish from diversion points throughout the Murray-Darling Basin. Researchers worked closely with irrigators and local manufacturers to refine an experiment to test a number of screen designs for Australian conditions. Fish screens are an important fisheries management tool used globally to protect fish populations whilst maintaining irrigator entitlements. A scientific exchange to the Columbian Basin in the USA exposed the group to the cost-share fish screening program which has been running in the Columbian River Basin with irrigators for almost 70 years now. Although many different screening approaches are currently applied elsewhere in the world, most of which would be suitable for application in the Murray-Darling Basin, it is essential that technologies are designed with the needs of local fish species in mind. Screens designed to not exceed velocities of 0.1 m/sec at the screen face should provide protection for many fish species and size classes in the Murray-Darling Basin. This guideline is aligned with acceptable limits in other parts of the world and there are currently many screening solutions available that are capable of meeting this in a cost effective manner. The team's findings provide practical solutions for mitigating fish injury and mortality at water infrastructure and the the next step is to apply world standards to develop a fish screening program in the Murray Darling Basin.



Electrical resistivity tomography (ERT) take 2-dimensional 'snapshots' of the underground landscape. The resistivity measurements tell us a great deal about the amount of salt, water and clay at any point in the deeper profile (up to 60 m deep). ERT transect running from native vegetation into fallow irrigated paddock in the Central Condamine Alluvia (tail drain at 120 m). Blue colour indicates highly wet and conductive clay layers.

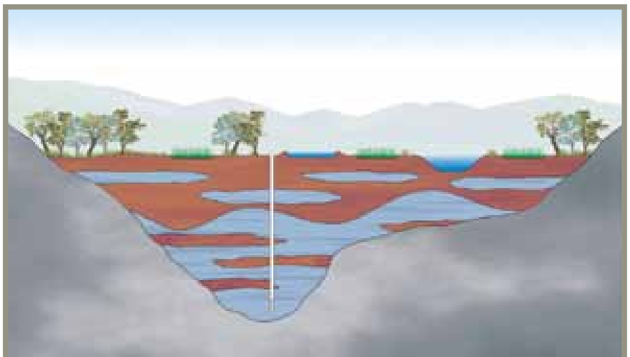
Deep drainage – an innovative approach

An interesting research direction emerged in this sub program which takes us away from floodplain ecology. Researchers in Queensland began to investigate the catchment scale trends and consequences of deep drainage. In the 1970s it was thought that there was no deep drainage through the clay rich soils in the Namoi Catchment. Groundwater models developed in the 1980s did not include any irrigation returns to the aquifer in the catchment water balance models. An idea materialized from the second workshop of the Northern Murray-Darling Water Balance Group held during the previous CRC in 2003.

An exciting new research method was developed by Dr Anna Greve, in her PhD. The newly developed 3D resistivity probes allow monitoring soil moisture status as well as the nature of water flow within the soil profile. This resistivity tomography system was applied to investigate deep drainage under irrigated crops, particularly cotton. The locations of large cracks which act as preferential recharge pathways were mapped through the clayey soils.

Scientists in Queensland's Department of Environment and Resource Management (QLD DERM) and the University of New South Wales have applied this technology to take 2D 'snapshots' of water patterns deep within soils of the Condamine alluvia using a Terrameter to further unlock some of the mysteries surrounding deep drainage. Transects were imaged through native vegetation and adjoining irrigated paddocks by Mark Silburn and Jenny Foley (QLD DERM) to look at historical changes in water and salt fluxes due to land use change. Soil water and soil chemistry were measured at spots along these transects to isolate the 'water story' from other factors that influence soil resistivity (clay and salt). All soils under native vegetation were found to be highly resistive (very dry) even when sparsely populated by trees. In contrast, significant long-term migration of water has occurred to deep within the regolith (up to 15 metres) in most irrigated paddocks. At some sites, fully wet zones of soil were seen in the entire upper four to six metres of the profile, and uniformly along the length of the transects. On average, these areas were found to be holding around 2.5 megalitres per hectare of water in the top six metres of the soil. These super-wet layers in the profile would not be a static store of irrigation waters, but would be draining into the deeper regolith at a rate proportional to the conductivity of the deeper clay and sand layers. There is tremendous potential to capture and use this currently under-utilised water. This research method is now being used in other activities such as the UWSRA Lockyer Purified Recycled Water project.

Groundwater



Groundwater is the term referring to water that occurs under the ground. Groundwater is a vast and slow moving resource that greatly exceeds the volume of other available freshwater sources. The study of groundwater is known as hydrogeology.

"This rigorous research effort magnified the impact of this work and to date all relevant government agencies have integrated the groundwater models developed during this research into their decision making process in the Namoi catchment".

Groundwater is an important resource that underpins a significant proportion of agricultural production throughout the Murray-Darling Basin. In times of drought, accessible groundwater resources of suitable quality have been found to underpin the resilience of remote towns, farm businesses and service industries. Groundwater has historically been managed in isolation from surface water, reflected in separate surface water and groundwater Water Sharing Plans in QLD and NSW. Initially, a suite of groundwater scoping studies were commissioned in six catchment areas to benchmark the current knowledge of groundwater conditions in key cotton growing regions. These scoping studies, plus the extent to which groundwater was an issue in a given region, governed the research investment. The CRC acknowledges Dr Noel Merrick, Dr Bill Milne-Home, Dr Derek Yates and Boyd Dent for their contribution to these initial groundwater scoping studies.

In 2005 the Namoi Catchment Management Authority (CMA) committed $2.4 million to the CRC. The CMA had identified that groundwater in their catchment was causing significant concern to irrigators, government and community stakeholders. For these reasons, most of the groundwater research conducted by the Cotton CRC concentrated in the Namoi Catchment.

Dr Paula Jones says *'The Namoi CMA had a strong commitment to working with the industry in a collaborative way which really paved the way for Namoi to get work done in their region."*

Researchers from the University of New South Wales (UNSW) the University of Technology Sydney (UTS), the University of Sydney (USyd) and the Australian National University (ANU) collaborated to explore the degree of surface and groundwater connectivity in three key areas – Maules Creek, Cox's Creek and the Peel-Mooki Rivers.

UNSW groundwater researchers installing a multi-port chemical sampling well.

The UNSW Connected Water Initiative team (CWI) delivered ground breaking research on surface and groundwater connectivity, for which they were nominated as one of two finalists in the 2011 Australian Museum Eureka Prize for Water Research and Innovation. The team sought to quantify the exchange of surface and sub-surface water in the Namoi Catchment, taking detailed measurements along the Namoi River reach between Gin's Leap and Narrabri. This research was supported by the Namoi CMA, Cotton RDC as well as the National Water Commission who also came on board to significantly financially support the research.

Led by Professor Ian Acworth and Associate Professor Bryce Kelly, CWI developed a multidisciplinary tool kit for the investigation of surface water and groundwater interconnectivity. The flow of water was characterised by a detailed field program which gathered and combined data to calibrate a 3D saturated/unsaturated groundwater flow model. The model investigates the implications of different surface water and groundwater allocations in these cracking clay environments. The research reflects how detailed climate, river flow, recharge, irrigation usage, water chemistry, geological, and geophysical data sets can be combined to improve our understanding of the processes surrounding the movement of water through a catchment.

Actual quantities of water exchanged between streams and aquifers are particularly difficult to measure. To this end CWI developed novel tools that utilise the observation of streambed temperatures to calculate the flow of water into, or out of, the streambed. Custom designed multilevel piezometers were installed in the alluvial sediments that contain the fresh water extracted for irrigation near the Namoi River and Maules Creek. These piezometers were used to undertake detailed water chemistry and isotope studies, at various depths throughout the 100 metre thick alluvial aquifer, to ascertain the age of the groundwater, and to examine how pumping influences the mixing of surface water and groundwater. Dr Martin Andersen says

'Our work shows that a significant proportion of the water being used in the Namoi Catchment, and most likely throughout the Murray-Darling Basin, is 10,000 to 20,000 years old. This water is now being replaced by modern river water, which is being pulled deep down, 50 m or more, into the alluvial aquifers as a result of groundwater extractions.'

In regards to groundwater quality, a study across the Namoi Catchment found that at some locations groundwater salinity was increasing at depth, probably due to saline water previously entrapped in the near surface clayey units being mobilised and moved to depth. Dr Wendy Timms says

'Once there is an impact detected at the point of use then significant zones of the aquifer will already have undergone an irreversible deterioration in water quality.'

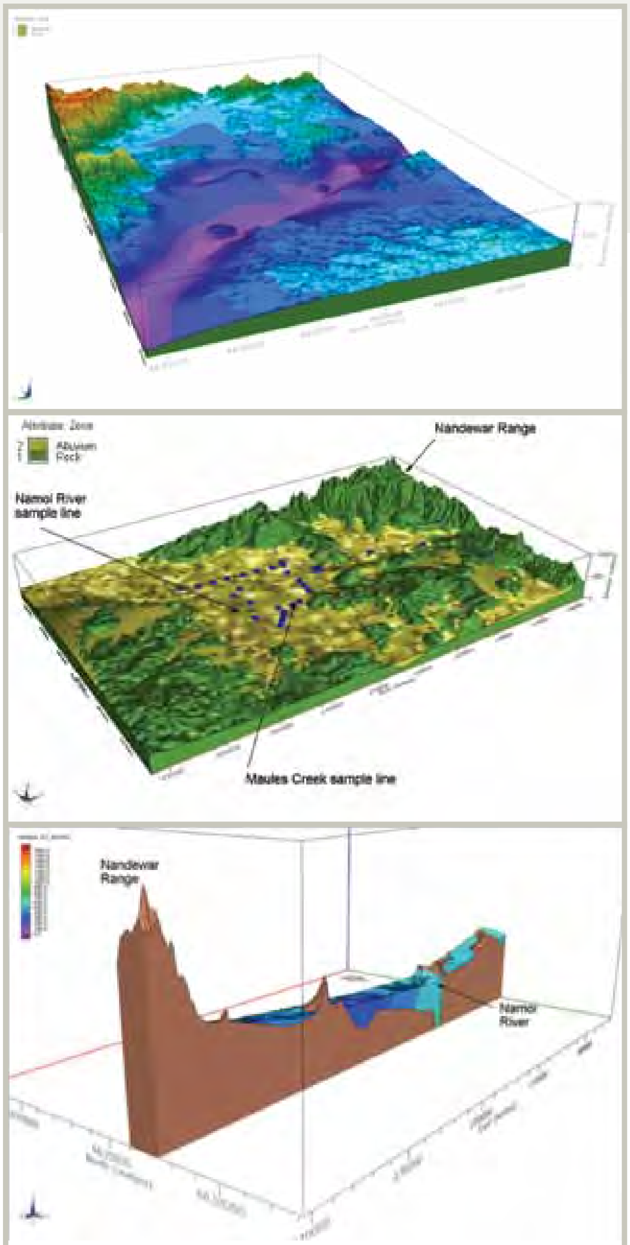
CWI have taken a multidisciplinary, state of the art approach to modelling with the development of new software that mines and collates data from historical government borehole driller logs and groundwater level measurements. The data is then displayed in an innovative interactive 3D environment, which provides a 3D conceptual geological model of the aquifer geometry and pathways of connectivity between the irrigation extraction boreholes at depth and the Namoi River. Understanding the 3D distribution of aquifer sediment types and their associated hydraulic properties is critical when coupling water chemistry and ecological processes to the movement of water through a catchment. Dr Bryce Kelly says

'3D modelling provides improved insights on recharge pathways, groundwater contributions to river baseflow, the impact of irrigation extraction, water quality characterisation, and the possibility of examining climatic variability and change on groundwater availability.'

The CWI model can be transferred to other catchments for improved understanding and consequently better management of the combined water resource. Groundwater Hydrographs for the Gwydir, Lachlan and Macquarie Bogan has recently been completed. Professor Ian Acworth from the University of NSW drew attention to some of the trends which have started to emerge across these catchments at the 2011 'Australian Cotton Water Story Forum' convened by Cotton Australia, Cotton RDC & the Cotton CRC. Ian said

'It is a good thing for groundwater extraction points to be well connected to a river, floodway recharge zone or mountain-front recharge zone. If your bore is not well connected to a recharge zone then you do not have sustainable access to water. Irrigators in areas remote from recharge zones need to be informed that under existing or proposed water sharing plans, groundwater levels will not recover in their lifetime.'

A collaborative approach to investigate the extent of groundwater connectivity was also applied in other parts of the Namoi Catchment. At the 2010 Cotton CRC Science Forum, Associate Professor Willem Vervoort was recognised for his "Outstanding Contribution to Postgraduate Education". Associate Professor Vervoort supervised many of the CRC's post-graduate students who have been involved in the development of a coupled surface and groundwater model for Cox's Creek, along with Dr Barry Croke (ANU) and groundwater hydrologists from UTS. These students include Dr Chris Vanags, Dr Floris van Ogtrop, Sarah Bennett and Dawit Berhane who all undertook their PhD studies in groundwater hydrology. As an example, Dawit Berhane investigated temperature, in conjunction with EC and other hydrological parameters, to understand surface and groundwater connectivity at different spatial and time scales. Heat has shown to be an insightful groundwater tracer to better understand hydrological processes that take place at different spatial scales.



MAULES CREEK 3D GEOLOGICAL MODELS: Understanding the 3D distribution of aquifer sediment types and their associated hydraulic properties is critical when coupling water chemistry and ecological processes to the movement of water movement through a catchment. 3D modelling will yield improved insights on recharge pathways, groundwater contributions to river baseflow, the impact of irrigation extraction, water quality characterisation and the possibility of examining climatic variability and change on groundwater availability.

Communicating research results and recommendations is a sensitive issue. Not all of the take home messages are good news for those who rely on groundwater for irrigation. Previous Catchment Program Leader Dr Paula Jones said

'As an independent broker of science, the CRC was able to find a careful path to deliver the research messages. Everyone focussed on the research and although they may not have liked the research outcomes they would agree with the science.' Says Dr Jones

This research portfolio brought irrigator groups, the department, CMAs, all together at the table. Researchers convened multidisciplinary steering committees and held field days for all interested stakeholders.

'Groundwater field days in the Namoi were held at a time groundwater was in demand and its management was in the limelight. Grower attendance and reaction showed the value the people placed on research coming from the industry.'

Underpinning the successful communication of CWI's key research findings and recommendations was Associate Professor Bryce Kelly's ability to connect with cotton growers and build rapport with diverse groups. Widely respected by the industry, Associate Professor Kelly was sensitive to the concerns of growers and irrigator groups when communicating aquifer and water quality decline. Professor Tony Jakeman (ANU) praised the CWI Team for their active engagement with industry stakeholders:

'It is unusual for scientists to engage in the comprehensive ways that this team has. They have run field days, town hall meetings and workshops, as well as engaging with their own scientific and related communities.'

In 2010 the Cotton Catchment Communities CRC and Namoi Catchment Management Authority convened the Groundwater Forum. Attracting over 40 attendees, from local government, mining and gas companies, state funded authorities and organisations, and universities, the interest in the event illustrated the importance of groundwater to the environment and economy of the Namoi valley. Furthermore it highlighted the significance of research undertaken through the CRC for managers and users of this vital resource. The event also explored the opportunities for collaborative approaches including agriculture, mining, coal seam gas and environmental managers for the use and management of groundwater, and attendees were encouraged by the prospect of future collaboration. Mike Williams, from the NSW Office of Water (NOW) says of the CRC and its researchers

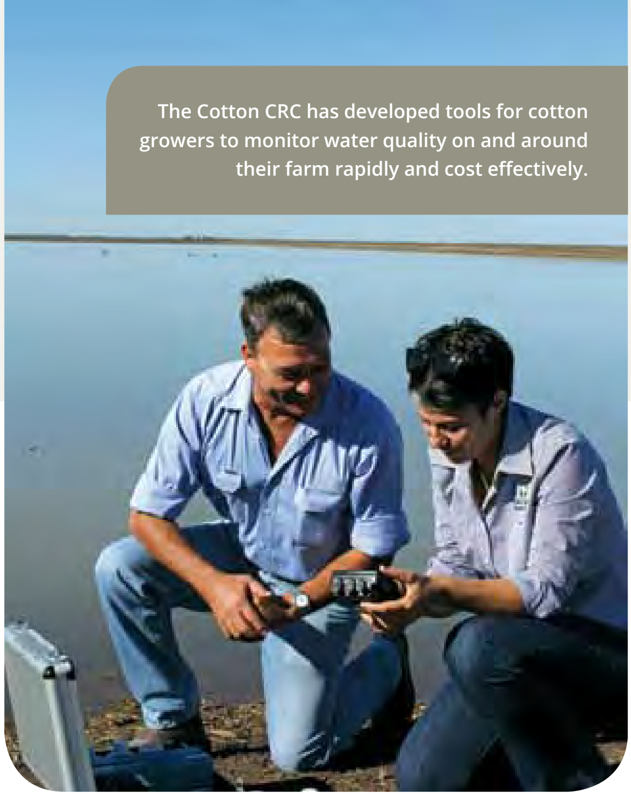
'There has been a willingness to share data, progress and information with NOW and the community that has been refreshing.'

The CWI research streams have considerably advanced the conceptualisation of river and aquifer connectivity in the Namoi region and demonstrated the impact of the groundwater irrigation extractions. The CWI Team's research findings are already being incorporated into local water management planning in the Namoi Valley. For example, the Peel Water Sharing Plan and irrigators in areas close to Water Sharing Plan limits are proactively adopting strategies recommended by the research team, including water rostering at low flows to protect riparian vegetation, aquatic ecosystems and general river health. The improved understanding of water flow between the surface water and groundwater systems has directly contributed to the allocation process locally and will also enable improved estimates of fluxes to be incorporated into regional catchment water balance models, thus improving their reliability and confidence levels. Mike Williams, NOW reflects,

'The legacy is the basis of solid science and on-going work that can be used to underpin NoW decisions.'

Clever cotton researchers vye for Eureka prize!

UNSW Connected Water Team (Professor Ian Acworth, Dr Wendy Timms, Research Associate Andrew McCallum, Dr Anna Greve, Associate Professor Bryce Kelly, and Gabriel Rau (missing Dr Martin Andersen), finalists in the 2011 Eureka Water Innovation Prize.



The Cotton CRC has developed tools for cotton growers to monitor water quality on and around their farm rapidly and cost effectively.

Water quality

The formation of the Cotton CRC in 2005 coincided with the early stages of the widespread adoption of genetically modified Bollgard® cotton varieties, mainstreaming of IPM and the subsequent use of softer chemicals. Prior to this time the Australian cotton industry had been under intensive environmental scrutiny over concerns about pesticide use. This was triggered in part by pesticide-related environmental incidents including fish kills and residues found in export beef in the 1990s. As a result, Cotton CRC effort was directed towards establishing how the industry could better manage pesticides in water and improve the quality of water on cotton farms and in cotton growing catchments. At the beginning of the CRC, when water was relatively plentiful, the focus was on establishing baselines for on-farm water quality and developing remediation processes to deliver both farm and catchment benefits using wetlands, for example, and as time drew on and water dried up the focus changed to the development of tools to better monitor and manage water quality.

A team of prominent researchers from the University of Sydney, led by Professor Ivan Kennedy and made up of Dr Angus Crossan, Dr Mick Rose and Dr Mitchell Burns, worked in collaboration with the Cotton Best Management Practices program to develop innovative ways for the cotton industry to become better stewards of chemicals. With water relatively plentiful in the early days of the CRC, research had initially focussed on using wetlands and storages as cleaning agents.

Dr Angus Crossan from the University of Sydney led two consecutive post-doctural research projects focussing on chemical water quality indicators:

1. 'Pesticide & Nutrient Remediation: Assessing Application and Integration with On-farm Storage Systems', and
2. 'Advancing environmental values in cotton catchments using risk assessment: practical methods of remediation including on-farm wetlands'.

Initially, Dr Crossan reviewed the environmental impact and development of risk assessment strategies within the Australian Cotton industry, particularly in regard to GM technologies and the associated reduction in pesticide use. The study found GM technologies can reduce potential environmental impact by reducing, or changing, pesticide use practice. Several results provided guidance to the cotton industry to improve their pesticide BMPs, at the paddock scale after rainfall, and the use of herbicides in drier climates. An experiment conducted showed that pesticide residues dissipate faster in actively composted cotton gin trash (GT) than in passively composted gin trash. Further studies, with respect to reuse of gin trash, are more likely to identify a more suitable industry-wide management practises. The need for continued collection of representative data on pesticides use by the cotton industry was highlighted. A number of publications were produced by the team at the University of Sydney based on their research findings including the book "Rational Environment Management of Agrochemicals: Risk Assessment, Monitoring, and Remedial Action, First Edition".

The recommendations for cotton growers which were brought together into a brochure: *'Design Principles for Healthy Waterways on Cotton Farms'* by Professor Ivan Kennedy (USyd) and Peter Jarman (UNE) which outlines key principles for increasing water quality and habitat value of cotton farm watercourses and storages.

In his subsequent project, Dr Crossan aimed to advance the cotton industry's capacity to manage water quality using constructed wetlands. However, growers at Moree and Emerald raised management concerns in relation to using storages to remediate pesticides in drier than average rainfall years. As a result, the team revised the scope, and research then focussed on the developing and pilot testing a simple water quality test kit. This kit enables rapid analysis and testing of pollutant indicators excluding chemicals in irrigation water, and preliminary results from the pilot study indicated that at least 15-30% of nitrogen is lost to the tailwater system as nitrate. This finding indicates significant economic gain can be made through improving the efficiency of nutrient use. Dr Crossan says

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

Simple tests for pesticides of concern would ideally be included in the kits however the technology is not yet available for 'dip stick' tests.

Simultaneously, three bioremediation techniques for the removal of pesticides from tailwater were investigated: phytoremediation (surface-flow vegetated wetlands), biofiltration (sub-surface flow wetlands) and development of an enzyme to degrade diuron to dichloroanaline. Using a constructed pilot-scale ponded wetland, USydney PhD student Dr Mick Rose found the removal of pesticide residues can be accelerated by aquatic plants and system design, through increased sedimentation, biofilm contact and photolysis. Importantly, diversity in tailwater return and water storage design will result in the potential for treatment of the diversity of pesticide chemicals used in the cotton-growing environment. Following on with the theme of remediation, Dr Robin Russell and her team at CSRIO made a major breakthrough which will expedite developments to complete the enzyme for DCA degradation. Although not successful in isolating an enzyme that degrades DCA as quickly as needed for commercial use, sufficient promise in the enzyme isolated to warrant further work to improve it.

As the drought drew on there was less and less interest in on-farm water quality, as storages were drying up, there was no excess water and growers were managing what water they had carefully and so the direction of the water quality research changed. The decision was made to spend some time looking into products and tools which would be useful to the industry and have broader market for the nation and internationally. Practical risk assessment techniques were developed, using probabilistic risk characterisation to support the effective management of agrochemicals at the catchment scale. In his research PhD student Mitchell Burns, from the University of Sydney, assessed the ecological risk for the herbicide diuron in the Gwydir River catchment. Mitch was able to identify sub-catchments contributing chemical loads, characterise potential pulse durations and their probabilities of re-occurrence. This could lead to an industry-wide cost-effective approach to managing pesticide risk in cotton catchments.

The Catchment Program's First Commercial Product

Test kits for the rapid detection of pesticide in water, based on ELISA technology and gold labelling were developed in collaboration with the University of Sydney and Tianjin University of Science and Technology (TUST). The test kits have been developed for the rapid detection of diuron, fluometuron, and prometryn. This project established both proof-of-concept for the technology and developed a series of prototype tests.

Pesticide use brings the potential for off-target contamination, and the quick tests will enable rapid certification that any contamination is below hazardous levels. Pesticide analysis has typically been an expensive process because of the costs associate with collection, transport and quantification. The quick test eliminates the need for collecting and analysing numerous samples at a laboratory, thus offering significant time and cost savings over the current analytical systems.

The test kits are easily portable and take less than 5 minutes to provide a yes/no result for ecologically hazardous concentrations of herbicide target chemicals in water. A provisional patent has been lodged in China and Australia for "a lateral flow device for the detection of diuron in a sample, methods of detecting diuron using the lateral flow device and a kit comprising the lateral flow device for the detection of diuron". The technology described in the patent includes the technology developed for rapid test kits for chemicals other than diuron. The research group is now working towards a multi-variate test for pesticides for both the cotton and sugar industries. The tests could be used to validate benefits from improved practices, such as *my*BMP growers in the cotton industry and may one day provide a critical step in green or eco-labelling of Australian cotton.

Jane Trindall says *'This is a very young product and the researchers have done exceptionally well to get to this stage in a very short period. The project really demonstrates the research capacity Ivan Kennedy has built over the years. The quick tests truly illustrate the cotton industries proactive approach to address social and environmental responsibilities.'*

Professor Shuo Wang from Tianjin University of Science and Technology, was originally one of Ivan's PhD students funded through CRDC in the early 1990s working on environmental fate of pyrethroids; he joined the CRC team as one of the inventors of the technology. Professor Wang heads a Key Laboratory for Food Safety with 10 academic staff and almost 100 post-graduate students at the Tianjin University of Science and Technology. As University Vice-President for International Affairs, Shuo is an important international collaborator.

Interestingly, the diuron quick tests are now being trialled in collaboration with the Cotton Research and Development Corporation (CRDC) to rapidly develop a risk assessment of diuron in for the Namoi and Fitzroy catchments. In view of environmental concerns, there is an increasing focus on the continued use of diuron. Recently, the APVMA reviewed and suspended its registration. Although the regulatory review is not complete, the preliminary indication is that application levels of 1.8 kg/ha may be retained for use where such use does not create a 'high risk situation'. The low-cost QuickTests provides a good opportunity to undertake low-cost sampling of rivers in cotton catchments. These data will be used to build on exiting knowledge of diuron concentration and ecological toxicity to characterise environmental risk.

Ecosystem services & biodiversity

Cotton growing farms have on average approximately 40% of their total land area dedicated to native vegetation, which is similar to the proportion of cultivation. Some growers are proud of their efforts to care for this natural heritage and are keen to improve their knowledge of flora and fauna at the farm scale. On the other hand, three questions frequently asked by agricultural landholders is *"Why should I maintain / create areas of native vegetation, how can it benefit me, and how do I know it will not add to my problems?"* At the outset of this CRC, little quantitative information was available about the provision of ecosystem services by vegetation on cotton farms and the effect of management on the ability of vegetation to provide these services. So in collaboration with catchment bodies and research institutions, the CRC set out to investigate and demonstrate the direct benefit that native vegetation has for farming businesses. This information is particularly important in agricultural landscapes where decisions concerning natural areas can result in trade off's for both biodiversity conservation and agricultural sustainability. For cotton and grain growers the ecosystem service of pest control directly benefits their business. Therefore one of the key focus areas was on natural pest control and the CRC examined the role of native vegetation on cotton farms for providing natural predators of cotton pests.

Associate Professor, Nick Reid from the University of New England says:

'Up until this time, much of the research already funded by the cotton industry through the CRDC and the Australian Cotton CRC focused on aspects of biodiversity, however, much of this research was targeted at production issues.'

It was time to reappraise cotton-funded research in a biodiversity framework. This sub-program set out to understand the provision and value of ecosystem services on cotton farms by improving the assessment, management and monitoring of biodiversity and ecosystem service resources in cotton growing catchments.

Ecosystem services

Associate Professor Nick Reid from the University of New England has championed ecosystem services research within the cotton industry. Supervising a team of PhD students within the CRC, his team has quantified ecosystem service provision and the trade-offs and synergies that occur with management. The CRC recognised his contribution to postgraduate education with an award in 2010. The achievements of Nick and his students from UNE are showcased below. Associate Professor Nick Reid says “The cotton industry has now funded biodiversity and ecosystem services research for over a decade and projects funded by the Cotton CRC have enabled significant advancements in this field”.

Two noteworthy contributions to the CRC are outlined below:

- Development of a methodology to place an economic value on ecosystems services, giving catchment managers a decision support tool to assist with the prioritisation and allocation of resources to achieve natural resource management outcomes (PhD student Dr Francis Karanja).
- Quantification of the ecosystem services provided by areas of native vegetation on cotton farms on the Lower Namoi Floodplain (PhD student Rhiannon Smith).

Rhiannon studied three ecosystem services, carbon sequestration, erosion mitigation and biodiversity conservation in five different native vegetation communities, common on the Lower Namoi Floodplain: river red gum, coolibah, myall, black box and grassland. Dr Rhiannon Smith says:

“A meeting was held initially with local cotton producers and other stakeholders to discuss the ecosystem services considered of greatest importance for the research project. As a result the project focused on quantifying carbon sequestration, erosion mitigation and biodiversity conservation (birds and plants) on cotton farms and adjacent public land. “

Rhiannon’s research was some of the first in the world to evaluate several ecosystem services across a large study area with a variety of vegetation types and climatic conditions. The results of this thesis will assist property owners and managers understand the values of natural and revegetated areas on-farm. It also provides targets for management to maximise vegetation condition for service provision in various ecosystems in agricultural landscapes.

personal profile

Rhiannon Smith

Rhiannon's passion is for *"the environmental side of cotton - and trying to make biodiversity real, quantifiable, and attainable to cotton growers".*

Rhiannon's PhD thesis *'Biodiversity and Ecosystem Services Associated with Native Vegetation in an Agricultural Landscape,'* ran along the vein of assisting growers to take advantage of future ecosystem service markets, including carbon storage and biodiversity conservation.

"I want to help break down the 'techno-talk' and heavier scientific side of things into an everyday farming language that the grower can use and utilise to work at the bigger picture," she says.

Rhiannon said that the Cotton CRC is a 'super-enthusiastic' organisation which has always been extremely supportive of her projects and encouraged her to continue research, for which she is personally very grateful.

"The Cotton CRC has given me great scope to investigate areas I am passionate about, while keeping it fully relevant to the cotton industry," she said.

Rhiannon's family came to the district from Nowra back when she was a toddler.

She recalls that *"pocket money was earned thanks to working weekends and holidays at the local University of Sydney Wheat Research Institute,"* where her love for the land kicked off when she helped as a research assistant in wheat breeding research.

"It was this time, along with strong friendships forged with farming families that ultimately lead to my stint at the University of New England (UNE), in Armidale, studying her Bachelor of Natural Resources," she admits.

Included in her studies was the completion of a Bachelor of Natural Resources Honours thesis in 2005, where the Cotton CRC funded a summer scholarship and a subsequent Honours thesis entitled: *'Biodiversity of Tree Plantings in Cotton Growing Areas of the Namoi Valley'.*

This was the start of her involvement with the cotton industry and the CRC. *"I have been researching ecosystem services in the cotton industry for some time now,"* she said.

Rhiannon has been a high achieving student winning a number of prizes and grants including the Australian Cotton Conference Best Student Poster in 2010.

Looking to the future Rhiannon Smith is about to embark on her newest research project for the CRDC which she says will be "continuing along similar lines to her PhD research" in helping Aussie farmers to better understand the role of nature and the wider environment in our farming systems, now and for the future.

KEEP IT MESSY: For the natural workforce to thrive it needs a diverse and complex work environment composed of different layers of living vegetation as well as rock piles, leaf litter and fallen logs.

A suite of projects led by Alan House at CSIRO investigated a landscape-sale view of the responses of biodiversity to the variety of land uses in mixed farming landscapes. This research has improved our understanding of biodiversity and ecosystem services on cotton farms, particularly in Southern Queensland.

Simple take home messages can be distilled from the results which are useful for growers, extension staff and NRM bodies to determine best-practice guidelines for managing terrestrial biodiversity and ecosystem services on farms.

Straw-necked Ibis

Grey-crowned Babbler

Birds on cotton farms

In eastern Australia many species of woodland birds are in serious decline. The *"Birds on Cotton Farms"* book was released in June 2006 and proved to be extremely popular. The response to this book was so successful that a further 1000 copies had to be printed to keep up with demand. Upon release of this book, a number of field days were held in the Namoi valley and were well attended. The momentum gained through the book was further built on by the research project in the Namoi valley where 138 species of birds were found on cotton farms in the Namoi valley. Evan Cleland of Birds Australia developed tools and information to enable growers to assess, monitor and manage their native vegetation.

A case study in the Border Rivers Catchment focused on the impacts of landscape modification and land use on the composition of avian species within woodland habitats. Results showed that landscape characteristics are secondary to the influence of an aggressive colonial honeyeater, the noisy miner. This study supports previous studies in the agricultural zone of eastern Australia where this species has been shown to be the primary driver of community structure. This species can dominate woodland remnants and excluded all species smaller than 55-60 g. Noisy miners contribute to trophic skew within woodland sites and the homogenisation of bird communities across the landscape. This PhD, undertaken by Oliver Roberston at UQ is intended to aid the improvement of best management practices for vegetation management within the cotton industry but is also applicable to Australian agro-ecosystems in general.

The Goodies-Natural Pest Control

Prior to the beginning of this CRC, little thought had been given to the non-crop vegetation (native trees, grasses and shrubs and introduced weeds) surrounding cotton fields and the role it may play in supporting populations of beneficial insects. In the initial stages of the CRC several PhD students focused their attention on this issue. A study which investigated various habitats and the spatial and temporal patterns of several generalist predator species found beneficial insects in pastures, dry land lucerne, native shelter belts, large river red gums and travelling stock routes adjacent to cotton fields. The results of UNE PhD student Dr Ingrid Rencken also highlighted, that the mobility of predators suggests a broader spatial scale should be considered when planning the spatial arrangement of these habitats in cotton-growing districts.

Consequentially, research scaled up from the plant and field scale and began to focus on understanding landscape level processes. A graph-theoretical analysis of the agricultural landscapes within the Macquarie Valley in NSW, demonstrated that fragmented landscapes may provide highly mobile pest species, such as *Helicoverpa armigera* with landscape-level enemy-free space, unless fine scale landscape connectivity exists to allow dispersal-limited enemies, such as *T. pretiosum*, to follow their hosts throughout the landscape. Dr David Perovic during his PhD study at Charles Sturt University was able to demonstrate the effects of the proportional area and connectivity of non-crop vegetation on the density of natural enemies within crops; and the movement of natural enemies from non-crop resources into cotton crops. Overall, the importance of non-crop areas in agroecosystems to enhance the activity of natural enemies and the need for a landscape level perspective in habitat management was confirmed.

Graph-theoretical analysis, which was introduced to conservation biology for the first time, demonstrated great potential in the pursuit of landscape level habitat management and the design of 'tailor-made' landscapes.

> A new paradigm: native vegetation is not a source of pests but rather an important harbour of beneficial insects.

To cement this emerging paradigm, that native vegetation is not a source of pests but rather an important harbour of beneficial insects, Dr Felix Bianchi (CSIRO) led a collaborative research project with Land and Water Australia "Capturing the ecosystem service of pest control from native vegetation." The three main outcomes were:

- Native vegetation supports consistently higher predator densities than crops throughout the year and produce relatively few pest as compared to crops.
- There is evidence that fields near native vegetation can benefit from pest control services from whitefly parasitoids and flying predators of cotton boll worm eggs - although this phenomenon is not always consistent across the year and fields.
- Fields adjacent to native vegetation do not have higher colonization of pests than fields 400m from native vegetation. On the contrary, the landscape with high proportion native vegetation had consistently lower colonization rate of aphids.

Based on all of the CRC research into natural pest control to date, the presence of perennial non-crop habitat, such as native vegetation, is thought to play

CASE STUDY

Biodiversity benefits!

Research has found beneficial insects are:

- Present in pastures, dry land lucerne, native shelter belts, large river red gums and travelling stock routes adjacent to cotton fields.
- Active during the winter months and using non-crop vegetation as egg laying sites.
- Moving from native shelter belts into cotton fields.

  This highlights the importance of non-crop vegetation, including native vegetation, as a source of beneficial insects and also a breeding site for some beneficial insects.

How can this research be adopted on-ground?

- Shelterbelts and isolated paddock trees between non-crop vegetation and cotton crops can greatly enhance ecosystem services by facilitating the movement of beneficial insects into crops.
- Many beneficial insects use native vegetation as reproduction and refuge sites. Native vegetation may therefore act as a green bridge between spring and summer crops, aiding with the colonisation of beneficials into newly planted crops.

Golden Orb Weaver (Nephila edulis) doing her bit for pest control.

Assassin bug consuming a Heliothis larvae.

Many beneficial insects use native vegetation as reproductive and refude sites. Native vegetation may therefore act as a green bridge between spring and summer crops aiding with the colonisation of beneficial into newly planted crops.

a crucial role in maintaining populations of natural enemies of pests in agricultural landscapes. Evidence across cotton growing regions in the Darling Downs, Macquarie Valley, and Namoi Valley, show that natural enemies (as well as some pest species) use native remnants as reproduction habitat, move between native remnants and crops, and colonize crops.

The spatial arrangement of patches of native vegetation - from which natural enemies colonize the surrounding landscape - is crucial for effective pest control in crops. What this means for landholders is that cotton and grain growers can benefit from maintaining and managing native vegetation by regulating the pest to natural enemy ratio in the landscape and that native vegetation management can potentially play a role in landscape scale IPM.

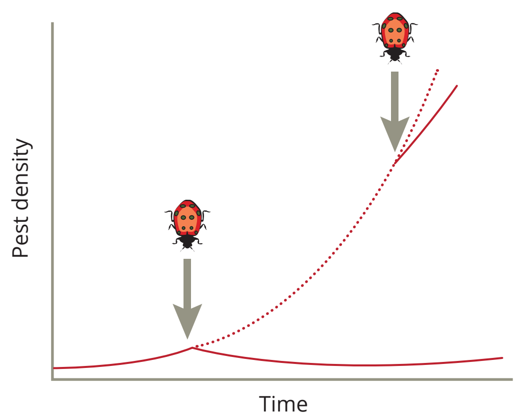
Pest suppressive landscapes

Following on from this line of investigation, a novel research direction was borne by Dr Nancy Schellhorn and her team, at CSIRO Ecosystem Sciences who began to look at developing IPM at larger spatial scales and the concept of pest suppressive landscapes. Nancy says

'Two observations triggered our interest in developing IPM at larger spatial scales. First, mobile pests do not recognize field or farm boundaries. Second, some landscapes appear less prone to invertebrate pest infestations than others, suggesting that there are features that may be managed to create more pest suppressive landscapes.'

But cotton may also play an important role in pest suppressive landscapes since it functions as a sink for *Helicoverpa spp* (i.e. a habitat where their population declines) and the reduced pesticide use is likely to favour natural enemy populations. In the Darling Downs, across three replicate landscapes, Nancy led a project to understand the role of *Bt* cotton in pest suppressive landscapes, specifically how increasing proportions of *Bt* cotton in the landscape alter the pest pressure of *Helicoverpa* spp. and egg parasitism and predation rates in *Helicoverpa*-susceptible crops. It was discovered, the landscape context influences *Helicoverpa* spp. population dynamics. When the landscape is dominated by fallow (observed in 2009-10 at Cecil Plains), *Bt* cotton functions as a population 'sink' and *Helicoverpa* populations rapidly decline from one generation to next. However, in landscapes with a considerable amount of *Helicoverpa* susceptible crops (e.g. sorghum and maize), the area of cotton has little influence on population decline beyond the borders of the crop, suggesting that moths are highly mobile moving widely across the landscape. This pattern held across three extraordinarily different years; 2009-10 was the last year of a 10 year drought, 2010-11was the worst flood in 100 years, and 2011-12 was 'normal'. These results have implications for the placement of refuges, suggesting greater flexibility with the 2km rule. However, this may only be true in areas such as the Darling Downs where the total area of cotton never exceeded 35%.

Timing of beneficial insect colonization is crucial



Early colonisation by natural enemies is crucial for keeping pests densities low.

GET CONNECTED: Productive cotton farms need to be connected with roads and rail to gins and ports. Similarly, a productive natural workforce needs to be connected to the native vegetation to access all the resources it requires.

Making an impact

Together the research undertaken under the banner of Ecosystem Services in the Catchment Program has vastly improved the scientific knowledge of the ecosystem services of native vegetation in agricultural landscapes. This knowledge has been used by growers, extension staff and NRM bodies to develop best-practice guidelines for managing native vegetation on farms. This in turn will enable growers to sustain production and increase profits and assisting catchment bodies achieve catchment targets. In 2009 research from this sub-program was incorporated into a training package entitled "Integrating Production and Biodiversity for a Sustainable Future'. The package, which was independently funded by the Namoi CMA, Western CMA, and Border Rivers – Gwydir CMA and developed by Greening Australia, draws heavily on Cotton CRC research. Modules from this training package are now being rolled out in the Border Rivers-Gwydir and Namoi Catchments and Resource Consulting Services (an independent RTO) has incorporated the relevant modules into their extremely popular 'Grazing for Profit' training.

Over the course of the CRC, the cotton industry's long-term commitment to ecosystem services research has progressively developed a valuable suite of tools and products that are underpinned by quality science and best practise, such as *my*BMP. Crucially in 2011, findings from the ecosystem services and biodiversity subprograms have been integrated into production-focussed publications for the first time. These include the new 'Pests and Beneficials in Australian Cotton Landscapes Guide', 'Australian Cotton Production Manual' and 'The Cotton Pest Management Guide'.

'The cotton industry has become increasingly aware of the lucrative benefits of enhancing native vegetation biodiversity on cotton farms and across the landscape. The 2011 new publication 'Pests and Beneficials in Australian Cotton Landscapes' has proven a breakthrough product.' says Jane Trindall.

Co editors Stacey Vogel and Sandra Williams show off the Pests and Beneficials in Australian Cotton Landscapes Guide the first publication which integrates findings from the ecosystem services and biodiversity subprograms into a production-focussed publication.

In 2012 the Cotton CRC was successful in obtaining a $440,000 grant from the Federal government's 'Caring for our Country' program. This project will bring 50 farmers together to contribute to the ongoing conservation and protection of biodiversity at a landscape scale across individual farms as well as neighbouring farms. Groups of farmers in Queensland and NSW will adopt best practice on their farms by integrating native vegetation into cotton production systems to increase the two ecosystem services of biodiversity and natural pest control.

CRDC's Bruce Pyke said

'Given NRM is already embedded in the industry's myBMP best practice system, and Integrated Pest Management is significantly dependent on a productive environment for beneficial species, this project has the potential to build on our vision for industry best practice'.

Partnerships

With the focus on developing and delivering catchment research outcomes, a vital focus of Catchment Program has been on forming and building natural resource management partnerships throughout cotton growing regions. The aim of this sub-program was to enable decisions on natural resource management by growers and catchment bodies to be informed by science-based best practice knowledge. Effective partnerships ensure co-investment in research and development whilst also maximising the reach of each organisations influence.

Several examples below highlight NRM partnerships within the Catchment Program.

Namoi Catchment Management Authority (CMA) partnership

From the outset the Namoi CMA came on board as a major collaborator investing $2.4 million in the Cotton CRC. Partnership funds were invested into groundwater research, the delivery of the Irrigated Cotton and Grains workshop series, employment of project officers, implementation of best management practices among cotton growers, on-ground natural resource management projects.

Along with most of South Eastern Australia, the Namoi Catchment entered its 17th year of low water flows in 2008. So a program began to implement water use efficiency best practise on cotton farms in the Namoi Catchment. This partnership provided training to build skills and capacity to produce more crop per drop. Cotton growers and consultants were given access to technical resources and advice, training and education and, significantly, incentive funds to implement best management practice on irrigated land. In excess of $1.2 million was invested by cotton growers, Namoi CMA and Cotton CRC to implement WUE best practise on cotton farms in the Namoi catchment.

On average, these farms have improved their WUE by 15%, equating to at least 5000 megalitres of saved water over 8000ha of irrigated cropping land, all of which is now managed under best practice. Stacey Vogel (Catchment Officer, Namoi CMA & Cotton CRC partnership) says

'Improving water use efficiency decreases deep drainage, reduces water logging and the risk of salinisation and also helps growers produce more bales of cotton per megalitre.'

Two jointly funded positions were in place in the Namoi Catchment. Stacey Vogel led the role out of the capacity building and on-ground projects while Kate Lightfoot and the Peter Verwey worked to increase the participation of Namoi cotton growers in the Natural Assets module of *my*BMP by assisting growers to prepare a property plan and monitor their groundwater quality. For jointly funded positions this created a direct rapport with industry, the ability to wear two hats and access the resources of both organisations, which consequentially maximised the reach and impact of both organisations with their target audiences. Stacey Vogel, Namoi CMA Catchment Officer was based at the Cotton CRC from its commencement and says

'This role has given me a lot of scope to develop professionally. I have had the opportunity to work alongside people and industry groups that I wouldn't have otherwise been involved with. I could still link to these networks in the future as I have been able to develop personal relationships and because I have that history with them.'

Significant on-ground outcomes were achieved which can be directly attributed to this partnership:

- 12 riparian instream structures installed in the Namoi Catchment.
- 15km of riparian zones along the Namoi River revegetated.
- 65km of riparian zones along the Namoi River conserved.
- 440ha of native vegetation on cotton farms in the Namoi Catchment conserved.
- 540ha of native vegetation on cotton farms in the Namoi Catchment enhanced.
- 5100ha of irrigated cotton land farmed sustainably for salinity and water use efficiency.
- 100 property plans for cotton farms in the Namoi catchment developed.
- 70% of cotton growing hectares in the Namoi with an up to date property plan.
- 5% of riparian area in cotton growing area in the Namoi managed for riparian values.
- At least 50% of growers regularly monitoring groundwater quality in the Namoi.

Indeed, the partnership with the Namoi CMA was one of the most effective partnerships in the Catchment Program. This partnership arrangement enabled both organisations to provide a continuous link between the generation of new scientific knowledge, the extension of this knowledge to growers and then the support to make these changes on their farms. An independent evaluation found:

'Without the partnership, neither organisation would have been able to achieve the same level of NRM outcome which resulted from better management practices, improved use of resources, conservation and re-vegetation.' (Roberts Evaluation Pty Ltd, 2009)

Why was this partnership so successful? Importantly, the partnership was characterised by an open and trusting relationship that was based on goodwill. Dr Paula Jones reflects

'The Namoi CMA were a willing partner, made time to sit on steering committees and so the interest and capacity or individual CMAs made a difference. We were able to get work done in the Namoi catchment and once the research momentum is built in an area we are able to build on it.'

The Sustainable Industries Initiative project 'Natural resource management delivery in the Australian Cotton industry' was a joint initiative between the Department of Agriculture, Fisheries and Forestry and the CRC which succeeded the Ag Sip project funded by the Queensland Government which focused on NRM extension in cotton and grain. Generally, these two projects aimed to assist the cotton industry address key NRM issues fundamental to the long term sustainability of the industry. Several key outcomes were delivered illustrated by two case studies below:

Trevor Elsden, Jenderrie Farms, reviews property planning funded by CHRRUP with Vicki Horstman (CHRRUP) and Susan Maas (QDPI/Cotton CRC).

Emerald irrigators unite to tackle environmental problems

Emerald Irrigators, along with other landholders, local government, state agencies, industry groups, the Central Highlands Regional Resource Use Planning Cooperative (CHRUUP) and the Fitzroy Basin Association (FBA) have combined to set up a plan of on-ground works over an area of 75,140 ha in the Emerald Neighbourhood Catchment. The group was rewarded with second place in the 2005 Queensland Landcare Awards for their efforts in delivering massive benefits to the environment and the community.

Landholders developed projects to install moisture probes, flow-meters, on-farm channel lining, dam lining and open channel conversion to pipeline, with the aim of reducing deep drainage by up to 18,200 megalitres a year. Projects have been identified to potentially reduce soil loss by 15,400 tonnes a year. Landholders and the Shire Council have identified over 4,000 hectares of riparian zones for protection and remediation. Over 85% of the area is covered by property management planning representing 80% of the Emerald Neighbourhood Catchment. The Emerald Neighbourhood Catchment Group through Integrated Area Wide Management (IAWM) has also put in place a landholder water quality database. Comet irrigator, Neek Morawitz, Chair of the Central Highlands Cotton Growers & Irrigators Associaton said

"The group is a successful combination of different sectors of the community developing projects together. Nearly all irrigators have taken part."

Best Practice Partnerships

For the past five years the Cotton Catchment Communities CRC (Cotton CRC) and the Namoi Catchment Management Authority (Namoi CMA) have had a partnership to work with cotton growers within the Namoi valley as well as other government organisations, industry bodies, research organisations and the general community to deliver natural resource management outcomes in line with the Namoi Catchment Action Plan (CAP).

research

"Without the partnership, neither organisatio
able to achieve the same level of NRM outco
from better management practices, improve
conservation and re-vegetation." (Roberts Evalu

The Namoi CMA and Cotton CRC worked collaboratively with research organisations to provide industry and agency extension staff and growers with the best available information to make land management decisions. Some of the research projects undertaken include:

- Identifying bird habitat requirements on cotton farms in the Lower Namoi. *Birds Australia*
- Development of a 3D geological mapping database interface to support interconnected groundwater and surface management. *UNSW, NWI*
- Riparian Conditions Assessment Index for Namoi River. *Ecological*

BIODIVERSITY

TARGET: Improvement in the health of native plants and animals on cotton farms within the Namoi Catchment.

WHAT WAS ACHIEVED: 440ha of native habitat conserved and 540ha of native vegetation enhanced.

BEST PRACTICE IMPLEMENTED: Pest animal and weed control, strategic grazing, re-vegetation, retention of dead trees and hollow logs, fencing to restrict stock access.

PRODUCTION BENEFIT: Healthier more diverse native pastures, better soil health and soil biodiversity through better groundcover, healthy habitats for natural pest controllers like spiders and damsel bugs.

NRM BENEFIT: Increased populations of native plants and animals and improved habitat conditions.

CASE STUDY EXAMPLE: David Grellman "Sandhurst"

"Subdividing our paddocks has made stock management much easier because we now know how much feed we have ahead of us"

WHOLE FARM WATER USE EFFICIENCY

TARGET: Improve WUE on cotton farms across the Namoi valley.

WHAT WAS ACHIEVED: 15% improvement across participating farms in WUE, 5000ML of water saved over 8000ha.

BEST PRACTICE IMPLEMENTED: Benchmarking and evaluating whole farm water balance and infield efficiencies and making necessary land management changes.

PRODUCTION BENEFIT: More bales per ML.

NRM BENEFIT: Reduced deep drainage and potential for salinisation of underlying aquifers.

CASE STUDY EXAMPLE: Paul Hawkins "Willawah"

"We are now able to better match our irrigation to our soil variability"

Bird Watching Routes of the Lower Namoi Floodplain *Narrabri Tourism, LHPA*

adoption

Forty-Five Cotton Growers across the Namoi valley undertook on-ground projects to improve the condition of their natural assets on their farm.

Namoi CMA Management Milestone	Contracted Cotton CRC Milestone target	Milestone ta achieved
Native vegetation conserved	365ha	440ha
Native vegetation enhanced	33ha	540 ha
In stream structures installed	6 structures	17 structure
Riparian areas revegetated	10km (1 Side)	15.6km (1 s
Riparian areas conserved	40km (1 side)	65.4km (1 s
Irrigated land farmed sustainably, especially for Salinity and Water Use Efficiency	2520ha	5103ha

PROPERTY PLANNING

TARGET: Increased number of Cotton Growers within the Namoi valley participating in the industry's BMP Program.

WHAT WAS ACHIEVED: 110,000ha of land covered by a BMP plan.

BEST PRACTICE IMPLEMENTED: Identification of key environmental and human risks on farm and development of action plans to address those risks.

PRODUCTION BENEFIT: A planning tool and process to monitor and evaluate management practices.

NRM BENEFIT: Improved sustainability of on-farm natural resources, improved ability to adapt to climate variability.

CASE STUDY EXAMPLE: Phil Morgan "Battery Hill"

"The Land and Water Management module has helped us identify our on-farm risks, identify what our compliance issues were, and gave us guidelines for managing the sensitive areas on our farm such as areas of native vegetation and the riparian zones".

RIPARIAN

TARGET: Improved health of riparian ecosystems on cotton farms within the Namoi valley.

WHAT WAS ACHIEVED: 90km of riparian vegetation within the Lower Namoi valley conserved and improved.

BEST PRACTICE IMPLEMENTED: Revegetation, weed and pest control, re-snagging of river to stop bend erosion and provide more fish habitat, bank battering, strategic grazing and fencing to restrict stock access.

PRODUCTION BENEFIT: Reduced streambank erosion and loss of valuable agricultural land and improved water quality.

NRM BENEFIT: Improved health of riparian ecosystems and surface water quality.

CASE STUDY EXAMPLE: The Namoi Demonstration Reach is part of the Namoi Aquatic Habitat Initiative which is a partnership with NSW Industry and Investment which restored 120km of the Namoi River and its tributaries between Boggabri and Narrabri. Around 26km of the demonstration reach is managed by cotton growers.

Manager Wayne Smoulders "The Myalls"

"I put a fence up along the river five years ago and let the trees regenerate and I can see how it holds the bank together".

extension

Approximately 50% of the industry within the valley participated in natural resource training.

Some of the training workshops and extension tools developed:

- Irrigated Cotton and Grains Workshop series
- 2007 Lippia Management Forum
- BMP Land and Water Management Workshop series
- Birds on Farms: Monitoring Biodiversity and Habitat Workshop series.

2008 Biodiversity in cotton landscapes Calendar (maintaining our natural workforce) and factsheet series

Birds on cotton farms (A guide to common species and habitat management)

Common Plants of grazing pastures on the Lower Namoi floodplain

Fishes on cotton farms (A guide to Native fish habitat management for north-west NSW)

Lippia Management Book

> "Growers need the financial implications of managing natural resources in order to understand the benefit in full"
>
> Olive (Sarah) Hood

Cotton grower, Brett Bidstrupp and Murray Boshammer from Total Agricultural Services Pty Ltd, Dalby, QLD.

Maximising water use efficiency in farming systems within the Condamine catchment

In 2007, with water becoming an increasingly scarce and consequently valuable input in production systems, the Condamine Alliance, Cotton CRC and DAFF worked together to improve water use efficiency best management practices on cotton farms within the Condamine catchment. This involved; training for cotton consultants and their grower clients, an economic evaluation of the benefits of adopting WUE practices, and incentive funding for water use efficiency evaluations.

Researchers and extension staff worked closely with consultants and growers in a mentoring capacity to achieve:

- 25% increase in cotton consultants with skills and knowledge in WUE.
- 2344ha of irrigated cotton land in the Condamine Catchment utilising WUE best management practice.
- Estimated water savings of 0.15ML/ha to 0.72ML/ha for the 13 participating farmers.

'By looking at the results of electromagnetic surveys and in-field water use efficiency assessments, we were able to identify the different soil types and look at how each responded under irrigation. We were then able to work out the best irrigation rates and inflows for the characteristics of the soil,' Cotton consultant Murray Boshammer said.

The economic evaluation found that the recommended changes resulting from each grower's water use efficiency evaluation would result in a positive return on investment for the grower.

A winning formula for NRM extension within the cotton industry was found to involve several interesting factors:

- Strategic and centralised coordination of NRM efforts is effective
- Capacity building of consultants is a strategic approach to building NRM into integrated management approaches on-farm.
- Local applications and examples remain a key to facilitating change on the ground.

(An external evaluation of the Sustainable Industries Initiative, Couttes J&R Managing and Evaluating Change, 2008).

Farm and catchment information resources.

Cotton growers caring for the land – a partnership with Landcare

In 2010 a Regional Landcare Facilitator in the Gwydir Valley was employed in partnership with New England North West Landcare Network, the Gwydir Valley Cotton Growers Association and Border Rivers-Gwydir Catchment Management Authority (CMA). Sally Dickinson was employed as part of the Cotton Development & Delivery team working to increase the uptake of *my*BMP and to work with grower groups to deliver catchment and farm research in the Borders Rivers Gwydir Catchment. This project aims to increase by 20% the cotton growers in the Gwydir Valley managing their farm and land sustainably and has steadily gain momentum with increasing grower attendance at regular grower meetings to discuss topical issues of concern to growers. Catchment Program Leader Jane Trindall says

'Refreshingly, Sally has been able to demonstrate that the issues of the farm and the environment aren't separate.'

A set of farm and catchment information resources and tools were developed that are consistent with good science, best practice, and practical adoption and catchment goals, including the:

- Birds on Cotton Farms: A guide to common species and habitat management (Cotton CRC 2006)
- Fishes on Cotton Farms: A Guide to native fish and habitat management for north-west NSW (State of NSW through Industry and Investment NSW and the Cotton CRC 2009)
- Pests and Beneficial's in Australian Cotton Landscapes editors Sandra Williams and Lewis Wilson (CSIRO) and Stacey Vogel (Namoi CMA)
- Lippia management *(Phyla canescens)*: Challenges, opportunities and strategies (The National Lippia Working Group 2008)
- 'Common plants of grazing pastures on the Lower Namoi Floodplain' (Cotton CRC 2009).

In 2011 a cotton grower survey found 96,323ha of native vegetation and riparian zones have been actively managed by 40% of growers on their cotton farm in the past 5 years. While not able to claim whole responsibility for these astounding outcomes the Cotton CRC has definitely played its part in achieving these.

Where it ends

'The most significant legacy of the Catchment Program is the attitudinal change seen both within the cotton industry and by typically environmental researchers in the value of environmental research embedded in an industry framework.'

Paula Jones, former Catchment Program Leader

Since the inception of the Cotton CRC Catchment Program in 2004, there has been a significant cultural shift in the way environmental research has been done in an industry context. Today we see attitudinal change in agricultural research scientists who are framing research questions and delivering the information to growers. Accordingly, the Cotton CRC has been able to broaden the context of entomologists, and has moved towards bridging the gap between the environment and production. The CRC has brought together agricultural and environmental science to look at landscapes where cotton is grown in an integrated and relevant way and an effective recipe to improve the environments in which cotton is grown. Jason Alexandra from the Murray Darling Basin Authority says

'The CRC has been successful in pushing the boundaries of bio diverse farms and farm landscapes'

Eighteen PhDs were carried out in the Catchment Program, illustrating the vital contribution the program has made to build the research capacity of ecologists, chemists and hydro-geologists, and the knowledge of natural resource in the northern Murray Darling and Fitzroy Basins. Dr Rhiannon Smith who has gone on to continue her research with the Cotton RDC reflects

'The staff at the Cotton CRC were always very helpful, supportive and understanding. They organised some fantastic opportunities to get researchers, industry groups, NRM bodies etc together and created some very fruitful discussions and collaborative projects. The CRC made our job as researchers easy and enjoyable. It is sad that all good things come to an end.'

Another central role of the Cotton CRC has been to link researchers with the farming community and government organizations. The Catchment Program has enjoyed partnerships with over 50 organisations who have invested nearly $7 million of external investment into this program (at least double the $2.4 million invested by DIISR). The Cotton CRC has been in the unique position of being able to effectively engage with irrigators, government decision makers, the community and other water users. This alone has given the Cotton CRC a greater capacity and ability to achieve outcomes from its research in cotton catchments. Associate Professor Bryce Kelly says

'For UNSW it has been very productive. The impact is now being seen via citations in government reports, and consulting documents'

Over the 7 years, the Catchment Program enjoyed partnerships with all relevant environmental decision makers in cotton growing regions. In a recent survey of these organisations approximately 75% of respondents would expect that the Catchment Program would be already contributing to very likely be contributing to natural resource condition changes. A similar proportion of respondents from CMAs or NRM bodies thought Cotton CRC outputs have assisted with achieving Catchment targets. There can be little doubt environmental agencies such as CMAs and NRM bodies see great value in a partnership with the cotton industry.

These strong relationships are important particularly as water becomes plentiful, and the industry emerges again as a major player in the northern Murray Darling and Fitzroy Catchments. There is great value for NRM organisations to remain connected to the cotton industry, as growers and consultants are key end users for natural resource management research, development and extension. At the same time, the cotton industry recognises the value of including environmental research in its portfolio, especially when the links between natural resource management and farming are tangible. Significant benefits still remain to be gained from industry and management bodies delivering the same NRM messages to growers, as well as having one point of contact for growers in regards to NRM issues. This can be achieved through collaborations. This crucial link of coordination and managing local issues by bringing partners together across multiple disciplines to extend their reach and build capacity will end with the conclusion of the Cotton CRC.

So what of the future for natural resource management research and development in the cotton industry? Natural resource management continues to increase in importance in the public eye, and continues to attract significant public investment, particularly in the areas of biodiversity and carbon. 80% of Catchment Program partners surveyed in 2011 saw the value of a future partnership with the cotton industry, the overwhelming majority citing water as the most important focus. Coal seam gas and mining is emerging as an important issue, as these are seen as industries with unknown ramifications on communities and catchments where cotton is grown. The Science Panel presiding over the 'Australian Cotton Water Story' made the recommendations for the industry relating to future water research: *Start a conversation on what success looks like in relation to delivering environmental water; and be active in groundwater research for the catchments, including its connectivity with the hydrology of the base rock formations in which coal seam mining is proposed.*

There are lessons to be learnt and successes to build on from the experiences with the Cotton CRC. It is reasonable to say the Cotton Catchment Communities CRC's Catchment Program has been the most successful environmental program by any Australian agricultural industry.

Dr Paula Jones

chapter three

community program

Following on from the success of the previous two CRC's, there was a growing awareness by the Australian Cotton Industry of the interrelatedness between itself and the broader community. Back in 2005, there was an understanding that within regional communities the industry stimulated employment, infrastructure, population growth and associated public and private services. It was also evident that regional communities in turn provided the industry with many of the services that it needed to operate successfully including a skilled workforce, transportation links and access to business, education and health services.

The industry and community's understanding of this interrelatedness and the point at which transforming technologies and other influences such as government policy and reforms could rapidly alter these relationships was unknown. At the time there was some evidence that a change to the use of GM cotton by the industry could directly impact upon local employment through reduced demand for manual weed control. Previously, manual weed control had been a significant employer of Aboriginal people and casual workers.

The new Community Program therefore set out to work with industry and regional communities to:

- Gain a greater understanding of the social and economic conditions of cotton growing communities
- Identify opportunities and strategies for enhancing the flexibility and resilience of cotton communities, including labour and regional business resources, and
- Identify strategies which enable rural communities and industry to understand, address and contribute to future natural resource policy issues, particularly in regards to the social and economic impacts.

Community Program Leaders

Brendan Doyle June 2005 to September 2006
Paula Jones October 2006 to June 2012


Paula Jones

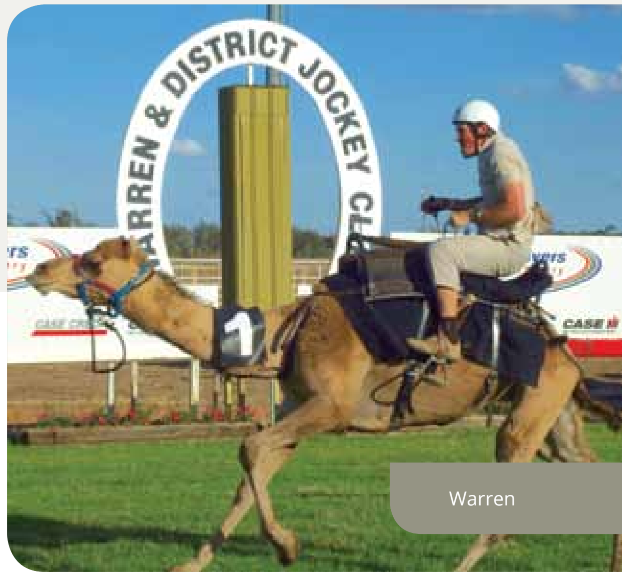
In the beginning...

The Cotton CRC's Community Program was a dedicated social research program and the first of its type for the cotton industry and also for an agricultural CRC. One of the first activities undertaken in the program to assist with focussing the research themes was to commission three key scoping studies. These early scoping studies addressed the three goals of the program and scoped the development of a set of economic and social indicators, identified opportunities for greater Aboriginal employment in the industry, and assessed the current condition of natural resource management (NRM) governance in the cotton industry.

'Reflecting on the social research the Cotton CRC has subsequently undertaken in the Community Program, these three scoping studies were instrumental in setting the future direction and activity of later research' says Program Leader Paula Jones.

The findings from these initial reports flagged that over the next ten years water was going to be the most important issue facing the cotton industry and regional communities, regional communities were going to be facing challenges that will be often complex and regionally specific, there would be an increasing lack of skilled labour to service the rural sector, and training incentives and collaborative partnerships which enable Aboriginal people to become active participants in the skilled labour market would be needed. These findings proved a constant theme throughout the Community Program particularly as the drought continued, new industries such as mining began to be established in these regions and government policies (water and carbon) were being developed and legislated.

Yong professional Meet and Greet



Warren

The Social and Economic Base
of Cotton Communities

At the start of the Cotton CRC, there was little understanding as to the socio-economic conditions of the communities in which cotton was grown or the size and extent to which cotton as an industry influenced the social and economic base of these communities. Typically the cotton industry undergoes boom and bust depending on climatic conditions, the availability of water, commodity prices etc. This makes cotton growing a risky business but its varying fortunes also affect the broader community through changing employment, demand for services and money injected into the local economy. There is also often perceived to be a gap between the industry and the broader community and yet they are closely reliant on each other in so many ways.

Roy Powell and Judith Stubbs highlighted this connectivity when they investigated the social and economic impacts of the cotton industry on regional communities in NSW and Queensland. They showed that for communities such as Narrabri and Warren, the cotton industry is an important and integral part of the economy. The industry directly generates 29% and 31% respectively of gross output compared to other centres such as Dalby with a more diverse economy where the industry contributes only 7% of gross output. These findings indicated that the social and economic response to the boom and bust of cotton was going to be different in each community. This has important implications for long term regional development in these communities especially in terms of creating a more diverse economic base to assist with smoothing out the 'bumps' caused by the fluctuating fortunes of the cotton industry and agriculture more generally.

In 2008, as this study was being completed, the drought continued to deepen and the Murray Darling Basin Plan was in development. Little was know about the likely content of the Plan and most of the focus was on the environmental aspects of the Plan. In contrast, there seemed to be an absence of research into the social impacts which changing water availability would have on those communities reliant on irrigated agriculture. In response, and building on the work of Roy Powell and Judith Stubbs, we ask Judith Stubbs to undertake further research into this issue and develop a more complete assessment of the relationship between community wellbeing, resilience and irrigated agriculture.

One of the difficulties with some social research is that it is often description rather than quantitative. The Stubbs work developed a methodology that took a rigorous statistically based approach to the questions of social and economic impacts from reduce water availability. *"By understanding the relationship between wider drivers in a rigorous and quantitative way we are able to get a better sense of the things that really matter to the community"* says John Storer from Judith Stubbs and Associates.

The Murray–Darling basin is a large geographical area in the interior of southeastern Australia, whose name is derived from its two major rivers, the Murray River and the Darling River. It drains one-seventh of the Australian land mass, and is currently by far the most significant agricultural area in Australia. It spans New South Wales, Victoria, ACT, and parts of Queensland and South Australia.

The Darling River flows from its headwaters in southern Queensland kilometers from its source in northern New South Wales to its confluence with the Murray River at Wentworth, New South Wales.

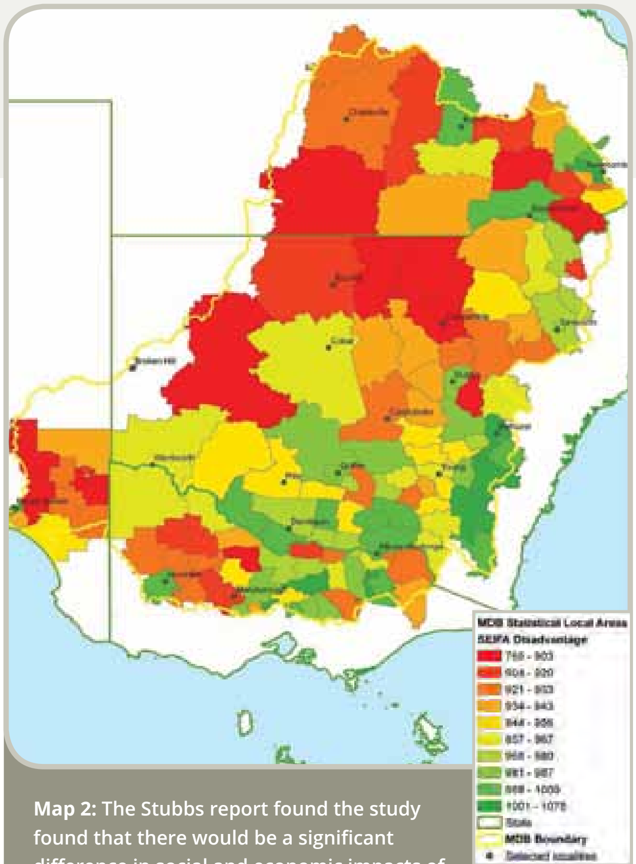
The River Murray flows for 2,530 km from the Australian Alps through New South Wales along the Victorian border and into South Australia before reaching the Murray Mouth and flowing into the Southern Ocean.

The 'Stubbs' report as it was known, was completed in August 2010, right in the middle of the run up to the Federal Election. This release date had been set prior to the election being called and there was great anticipation from the community and irrigation groups as to the report findings. To handle the situation in a balanced and fair manner we provided confidential briefings with the Chair and CEO of MDBA at the time as well as various irrigation and farming group representatives. We also briefed DIISR and advisors of several Federal Minsters whose portfolio was relevant to the Plan.

Given that little information as to the likely scale and location of water cuts was available at the time, the study chose three different levels of water reductions which were being discussed at the time and assumed that they would be across the whole Basin. These figures were a 10%, 25% and 50% reduction in water availability. The study found that there would be a significant difference in social and economic impacts of water reductions when considered at different geographical scales. At the national scale, the impact was not considered to be that great in terms of job losses or national GDP. At the local scale, those communities with little diversity in their local economy and with a strong reliance on irrigated agriculture were most at risk and losses of job and population were predicted.

These findings proved to be controversial at the time and there was strong debate both between academics and in the media as to whether the predicted job losses were accurate. The project as a whole received strong national media and community attention with over 250 different media citations and over 700 hits on the Cotton CRC website from government agencies, community and industry groups. The researchers were also asked to appear twice before the 'Standing Committee on Regional Australia – Impact of the

Map 1: Cotton growing communities in the Murray darling basin.
Source: JSA 2009, ABS 2006 Agricultural Census - Agricultural Commodities Small Area Data.



Map 2: The Stubbs report found the study found that there would be a significant difference in social and economic impacts of water reductions when considered at different geographical scales. Source: JSA 2009, ABS 2006.

Murray Darling Basin Plan on regional Australia' and the work was cited over 50 times in Hansards by various community, local government and industry groups as part of their submissions to this investigation. The report also highlighted not only the importance of social science but also the demand and need for this type of research in national debates and policy development. Use of this research exceeded our expectations and has frequently been cited in submissions to various Parliamentary and Senate Inquiries by community and agricultural groups across the Basin.

The widespread use of this research was largely due to the work moving social research from being merely a descriptive inquiry to a quantitative one. *"Once you have an understanding of causality you have an ability to make change. The data actually gave communities an entry point to engage with our demographic system. They could challenge the science and question the policy and this is a very powerful thing"* say John Storer.

Like the Stubbs report, the Wee Waa Drought study also received widespread media attention. This study was first undertaken in 2004 by Guy Roth and Tim Drew at the end of the Australian Cotton CRC. Wee Waa is a small community of approximately 2000 people west of Narrabri and has an economic based strongly reliant on agriculture and more particularly cotton. At the time there were a number of studies examining the impact of drought on farmers but not small rural businesses and communities.

In hindsight, 2004 was really just the beginning of the drought but its impacts were already being felt on Wee Waa. The study showed that compared to 2001, the gross turnover of surveyed businesses had dropped by 47% and permanent staff numbers were only 69% of the 2001 levels (a time off peak cotton production in the Namoi valley). This drop meant that people were leaving town and the local primary school numbers had already dropped by 15%.

In 2007, Stacey Spanswick, Guy Roth, Tim Drew and Paula Jones in conjunction with the Wee Waa Chamber of Commerce revisited the study given that the drought had continued to worsen. This time the findings were even more revealing with gross turn over falling by 52% based on 2001 levels, the numbers of permanent staff had declined by a further 60% from the 2004 level and of those terminated employees, two thirds had left the community. The social impacts were also beginning take hold with a 21% decline in student numbers across the community's schools and a doubling of people accessing health support and counselling due to the continued drought.

While the findings were bleak and attracted a lot of media attention, the Wee Waa Chamber of Commerce used it as a means of being proactive given that they could now support their arguments with actual data. They developed a strategic and marketing plan for the town and sought funding for various projects identified in the strategic plan using the study as evidence of the social and economic decline in the town. As a consequence, Wee Waa now has a new skate park for local kids, library facilities are being updated, a water recreational area for the local lagoon is under development, and the Chamber of Commerce has held various events in town to boost morale and promote local businesses.

In a footnote to this research, the Cotton CRC commissioned a final study on the community of Wee Waa in early 2012. This followed on from the drought breaking in 2010, two large cotton seasons and floods. Initial results available at the time of writing indicated some early signs of Wee Waa's recovery such as a 77% increase in business turnover however the study also showed that there was:

- No increase in employment, indicating the impact of drought lingers on, although the upcoming cotton ginning season is predicting a large increase in the casual workforce.
- A 38% change of ownership in the business owners of main street
- School numbers have increased, but not back to 2004 levels.

The recovery of Wee Waa has in part been tempered by several significant floods that isolated the town in 2011 and 2012 and broken its momentum.

An emerging theme in this area of research has been the importance of community wellbeing and resilience in the face of various climatic, financial and social adversity experienced over the last decade. As a way of tying this research theme together, one of the final projects to be undertaken in the Community Program was that led by Anthony Hogan (ANU) and his collaborators from Canberra University, the University of South Australia, Flinders University, Economic Solutions and Instinct and Reason. In partnership with the Namoi CMA and RIRDC, the team identified the critical social and economic attributes that make up an adaptive community and developed a decision making tool which communities can use to assess the likely impacts of further change to the social and economic base of their community.

This work will continue on beyond the life of the Cotton CRC and is being incorporated into the Namoi CMA's new resilience based Catchment Action Plan (CAP). The inclusion of this type of social research into the CAP is the first of its kind and offers the Namoi CMA a more robust way of measuring and monitoring community resilience in the longer term. It is also receiving significant interest by other state and federal government agencies and we hope it becomes a widely used method of measuring and monitoring community resilience in other regions.

Wee Waa

community program

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Employment and Business

Some of the largest social issues that have plagued rural communities for a long time are the steady decline in population as young people move away for education and job opportunities, attracting and retaining those skilled professionals that rural businesses require and how to better connect and work with the Aboriginal community. They are enormously difficult problems to solve and require a variety of approaches to make an impact. In this part of the Community Program, we addressed these issues through a combination of research and action based related projects.

Our research orientated work focussed on identifying innovative businesses in rural communities and exploring various opportunities to better connect and work with the Aboriginal community. Complementary to the research was the participatory side of the program which involved working with Chambers of Commerce, Local Government, business houses, and Aboriginal groups to develop and trial some of the research findings. This approach has been an extremely successful means of involving the community and industry directly in social research as well as providing researchers with a greater links to rural communities.

Small to medium enterprises are the economic life blood of regional communities. They generate economic growth, local employment and provide important services to larger sectors like agriculture and mining. Many of the regional communities in cotton growing regions are simultaneously loaded with opportunity and but also extremely high risk. Innovation and flexibility is the key for the long term survival of many businesses in regional communities where change from such things as commodity prices, exchange rates, and climatic conditions and can be rapid and dramatic. In an attempt to better understand what makes some regional businesses succeed and other fail, Bernice Kotey (UNE) investigated the adaptive strategies and capacities of small and medium enterprises (SMEs) in a sample of cotton communities (Warren, Wee Waa, Moree, St George, Dalby and Emerald).

A different face of cotton communities.

Getting social at Yong professional Meet and Greet - The project was trialled in Narrabri and Wee Waa with an overwhelming response, up to 70 people attending each of the many events.

Innovations undertaken by rural businesses included the addition of new products/services to existing lines (diversification), entry into new markets, and mergers with similar businesses. These types of activities tended to be higher risk only a few businesses had successfully undertaken these. By contrast, the innovations described by the majority of the businesses were incremental in nature, involving changes to various aspects of their operations, and were implemented in response to specific problems.

The areas that plagued businesses the most and for which they implemented various innovative responses were attracting and retaining customers and employees and collecting monies from debtors. Innovations to deal with these problems included the expansion of their target market, a promotions strategy, variable pricing strategies, customer service, an internet profile, accounts payable management and human resource management.

These initial findings led to the further development of this project whereby, the principal researchers are now directly working with community members to select and develop systems for implementing programs to enhance the environment in which businesses in the communities operate. Community members are participating in the research process as co-researchers and activities are underway in St George and Moree to implement community decided activities to support and encourage local business.

Another support mechanism introduced by the Cotton CRC for the community and local business was the 'Young Professionals Network. This was developed following the findings from the socio-economic study by Roy Powell. In this study it was shown that many cotton communities have experienced a major loss of young people, especially in the 20 to 40 age bracket. Many young people leave these communities to gain further education and work opportunities, meaning that attracting and retaining young professional staff has become an issue for many businesses in these rural communities.

The 'Young Professionals Network' brought together young people (early 20s to late 30s) in the community to develop and expand their professional and social network. The project was built on the premise that when young professional people are actively connected in the community and have well established networks, they are more likely to remain in, and contribute to, the community.

community program

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In many communities where cotton is grown there is a significant proportion of the population which is Aboriginal. The initial scoping report undertaken by Maria Cotter (UNE) stated that

'cotton industry programs that support education, training and mentoring of Aboriginal students on pathways to employment both within the industry and allied services are the most readily identifiable "Win-win options". Underpinning such general educational support programs should be a more rigorous participatory action research program that enables the examination of, for example, entrepreneurial Aboriginal businesses associated with industry initiatives.'

Based on these recommendations, the Community Program then set about developing projects which would contain research but also attempt to better connect with the Aboriginal community.

Once complete, Donna Moodie will be the Cotton CRC's first Aboriginal PhD graduate. Donna has focussed on how to engage effectively with Aboriginal communities with a view to promoting long-term, resilient relationships. As an Aboriginal person herself Donna is able to explore this from an Aboriginal perspective which makes the research very unique. Central to this work has been the inclusion of case studies using Aboriginal methodologies to explore engagement opportunities. It is anticipated that the findings will assist the cotton industry and Aboriginal people to improve their current levels of engagement, have a greater appreciation of traditional ecological knowledge, and increase potential for a genuinely sustainable future.

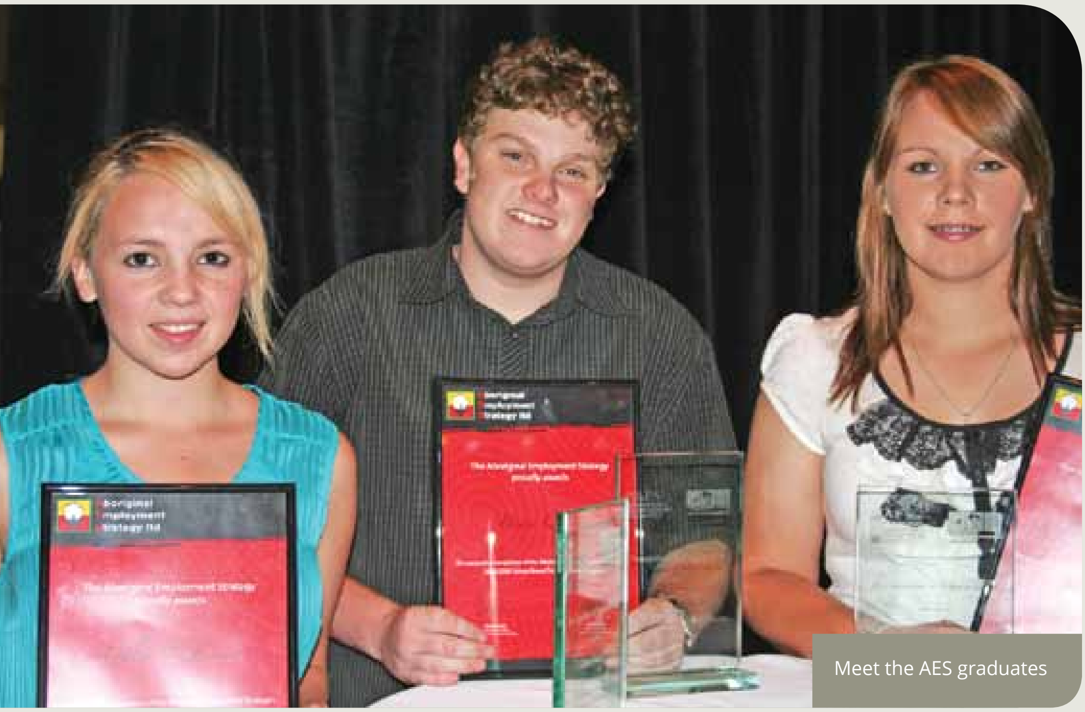
Complementary to this has been the Gomeroi Skills audit which the Cotton CRC has been undertaken in conjunction with Narrabri Coal Operations, the Narrabri Coal Project Implementation Committee and CRDC.

Gomeroi Country extends broadly from the Qld / NSW boarder region to Tamworth, Aberdeen/ Muswellbrook, Coonabarabran and Walgett. The Gomeroi people are the traditional owners of that Country. The communities within this region have significant levels of Aboriginal populations and the economic conditions of these communities are changing rapidly. Currently agriculture, and cotton in particular, underpin the economic base of this region, however mining and resource extraction industries are developing rapidly and this is creating a massive demand for skilled labour.

To begin to address both this increasing demand for labour and to increase Aboriginal participation in the local workforce, this study was one of the first to undertake a broad skills audit of the Gomeroi people living both on and off country. The outcome of the skills audit has been a clearer picture of the existing skills of the Gomeroi people and identification of the areas in which training and education are needed. The next stage for the project partners is to begin developing suitable courses for the audit participates with the ultimate view to be being able to fill many of the agriculture and mining jobs with Gomeroi people from the region.

The outcomes from the Gomeroi skills audit project also closely align with the Schools Based Traineeship that the Cotton CRC ran in conjunction with the Aboriginal Employment Strategy and CRDC. Schools-Based Traineeships combine paid work, industry recognised training and credit towards the NSW Higher School Certificate (HSC). Students complete the traineeship at the same time as the HSC, and it involves 100 days of work over 2 years.

Over the 2 year traineeship students worked with staff from NSW DPI, CSIRO, the Cotton CRC and CRDC. The program provided the students with the



Meet the AES graduates

Chloe Pokarier-Baker, Narrabri, Business Skills Cert II. Chloe went onto further tertiary studies. Her advice: *'Work, learn and get paid at the same time'.*

Beau Quirk, Narrabri, IT Skills Cert II. Beau found work locally in IT. His advice: *'Go for it, learn from it and enjoy it'*.

Bronwyn Scott, Wee Waa, Rural Studies Cert II. Bronwyn, gained full time work at the Cotton Research Centre and hopes to do further studies. Her advice: *'Take up a traineeship and don't give up'.*

necessary employment skills and training to enable them to access some of the great jobs available in the industry. More specifically, they developed skills in laboratory techniques, IT, office administration and primary industries. Since its inception, 5 students have successfully graduated from the program and gone on to further employment or study. This has been a great achievement both for the students but also for the industry and Cotton CRC where we are able to clearly see the value of this type of investment.

One of the Cotton CRC's final efforts in working more closely with the local Aboriginal community is through Jane Trindall's project 'Cotton growers working together for a sustainable future'. Jane was successful in being awarded a large DAFF grant through the Caring for our Country Program. As part of this project, Jane is leading a pilot project to enhance the job skills and employment rates of Aboriginal workers, while also boosting biodiversity on local farms. The Cotton CRC Trainee program has created farm based employment opportunities for local Aboriginal people as part of the industry's commitment to 'closing the gap'.

The Aboriginal 'Cotton Trainees' are playing a key role in implementing critical revegetation projects while building their skills in natural resource management. Trainees have taken on environmental rehabilitation projects in local bushland and along rivers and creeks. They are also being trained through host farm placements in agricultural activities such as machinery maintenance, irrigation system operation, crop planting and harvesting.

George Lamb, Gus Mason, Shane Toomey, and Blake Hilderson are the first four recruits to take on the 12 month Cotton Traineeships course which will culminate in a Certificate II in Rural Production qualification. George Lamb says working on the host farms has been far more enjoyable than other jobs and employment programs he's been involved in

'*There's a big range of things to do on a farm so that it keeps the job interesting. It doesn't get repetitive and monotonous*', says George.

Lyn Trindall *(CEO Narrabri Aboriginal Land Council)*, **Jane Trindall** *(Cotton CRC)*, **George Lamb** - front *(Trainee),* **Blake Hilderson** *(Trainee)*, **Gus Mason** *(Trainee)*, **Shane Toomey** *(Trainee)*, and **Verity Gett** *(TAFE Trainer).*

Training is provided by the TAFE NSW New England Institute as part of a flexible program negotiated with the host farm businesses to ensure trainees are in the workplace when they're needed most. Since the project began, George and the other trainees have already tried their hand at irrigating cotton and working with sheep, mustering, drenching and moving stock, and are revelling in the wide variety of work each day presents,

'It's challenging and interesting. Before I started I thought it would be just hard work. Instead it is hard work but it's also interesting work and it keeps you motivated. This is heaps better than sitting around and not working', says George.

For trainees like George Lamb, the project has already proven to be extremely valuable. George says he's felt far more welcome as a CRC Cotton Trainee than he has in previous workplaces because he's been treated as part of the host farm team. George says work in the farm sector is now definitely a career path he'd like to pursue, *'By far this is one of the most useful and interesting courses I've ever done.'*

This is the best type of endorsement the project and Cotton CRC could wish to receive and makes all our efforts worthwhile.

Reflecting on the Past and Planning for the Future

One of the things the Community Program has been able to quantify is the connection of the cotton industry to the social and economic base of it communities. This hasn't always been the case particularly in the early stages of the industry's development when it was considerably smaller and it was forging a major change in agriculture. Both the cotton industry and its communities have a long history of adaptation and change over time. They have learnt to work together and deal with all the challenges that an emerging industry brings to rural communities. Reflecting and understanding this history of adaption is timely as many rural communities are facing similar challenges again with the emergence of the extraction and mining industries into these regions. An appreciation and understanding of this history also provides a useful starting point for both the community and industry in planning for the future.

The modern Australian Cotton Industry started in the late 1950's and change was rapid.

'As a relatively young agricultural sector, modern cotton growing in Australia did not follow the pattern of previous more conventional agricultural pursuits, such as grazing, or wheat and sheep farming' say Wendy Shaw (UNSW).

'*There were significant challenges both for the industry and the community including extreme natural events, major changes in water policy, pest and weed issues, environmental audits, technological changes, and socio-cultural changes'.*

Wendy's research investigated how the industry and community have responded to these challenges. Firstly, by understanding how farmers have adapted their farming practices to local growing conditions and to technological innovations over time and, secondly, to improve our understanding of how cotton communities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have also adapted in response to these changes over time. Critical to the ongoing growth of the industry and communities have been their capacity to adopt new ideas, technologies and farming practices as well as adapt to change. The cotton industry's *"culture of sharing ideas and strategies, of sharing information to disseminate amongst local growers, has ensured good working relationships between communities"* says Wendy.

Some of the ways in which this work has brought industry and community people together are through the personal interviews and the production of a movie length documentary. The first cut of the documentary was screened at the Cotton CRC's final Science Forum in March 2012 and was extremely well received. Once complete, the documentary will capture an important point in time for both the industry and rural communities.

"a culture of sharing ideas, strategies, and information to disseminate amongst local growers, has ensured good working relationships between communities"

While the history of the industry's development and the community's response may not initially seem relevant to the future, there are strong parallels and lessons that can be drawn from this work. This is particularly pertinent when looking at the issues that the industry and rural communities are facing now with the emerging extraction and mining industries moving into the regions, ongoing concerns about water, agriculture and labour.

A project which builds on this is *'Australian Cotton Futures: Building capacity for resilient and adaptive communities'* by Roel Plant and Tim Prior from UTS. This research investigated how the industry is likely to change and what capacity the community has to evolve with these changes. Building community and industry capacity to cope with, and benefit from, future change requires an understanding of the future and its uncertainties in terms of demographics, the work force, new technologies, emerging rural industries, climate change impacts and water stress.

Members of cotton communities interviewed in this research had varying perceptions about the future of cotton and the extent to which it might contribute to their personal futures, and the future of their wider communities. Tim Prior said

> *'For the most part, these perceptions were connected to current concerns about environmental uncertainty and water security, regional economic development (particularly in relation to the growing importance of the mining sector especially LNG exploration), and the adaptability of cotton growers to environmental and economic cues'.*

The research has shown that issues like falling cotton production and changes in water policy have tangible flow-on effects for the community for example falling population, and mobilisation of skilled labour. In good seasons, cotton is the most profitable agricultural activity in cotton regions and the economic benefits that its production yields can be felt by businesses and non-cotton members of the community alike.

"Community members who took part in this research generally hold strongly positive attitudes to the future of their communities, and felt that cotton would play a central role in the future" said Tim Prior. This highlights the fact that most rural communities continue to be dependent on agriculture and see agriculture as an important contributor to the social and economic vitality of these communities.

NRM Policy and Governance

Over the course of the Cotton CRC, the importance of natural resource management policy and its governance came to the fore and increasingly the cotton industry and its communities were being asked to prepare and respond. The importance of various NRM policy and governance was being amplified by the continuing drought and the resulting preparation of the Murray Darling Basin Plan, as well as the increasing recognition of climate change and public demand for the government to take action. While the Cotton CRC's Farm and Catchment Program addressed the production and environmental issues around water and climate change, the Community Program focussed on identifying strategies which enabled rural communities and industry to understand, address and contribute to future natural resource policy issues, particularly in regards to the social and economic impacts.

This included investigating:

- the possible impacts of climate change for the cotton industry and the development of economic, social and environmental sustainability indicators for the cotton industry;
- the social and economic impacts of climate change, technology and water policy for farmers;
- the capacity of industry, regional NRM bodies and government agencies to collectively manage NRM issues especially water;

community program

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In 2005, the science was beginning to emerge regarding the potential impact of climate change on different regions within Australia particularly in terms of changing temperatures and rainfall patterns. From a cotton industry perspective however, there was little knowledge as to what these changes might mean to the growing of cotton especially given its water demands and preference for hot days during the growing season. One of earliest studies undertaken in the Community Program attempted to better understand what the likely impacts would be and explore some of the adaptation options available to the industry and community. David McRae (DNRW) found that some of the projected increases in temperature will have both positive and negative impacts for cotton growth depending on whether the location is currently considered a cool or hot cotton growing region.

The capacity to adapt to climate change is important not only for the industry but also regional communities. The recent drought demonstrated how climatic conditions can impact on an industry which in turn directly impacts on the economy of the supporting communities.

In many cotton irrigation regions, surface and groundwater resources have been increasingly stretched. As a result there have been substantial trade-offs between competing environmental and productive uses of water. In the future, climate change and variability could lead to substantial environmental, economic and social impacts as an increasingly scarce supply of water is shared between these competing uses. Much has already been done in terms of negotiating the trade offs for competing demands of water in cotton regions however a better understanding of the future impacts was needed.

Narrabri

Cotton Communities Calendar 2009

To begin to look at the different options for sharing both groundwater and surface water resources as well as consideration of the linkages between these systems and the social, economic and environmental values associated with this water, Tony Jakeman and his team undertook a collaborative multidisciplinary project focussed in the Namoi Catchment. The team has been able to produce a well-integrated model that combines climate and policy drivers with adaptation options to predict economic and environmental outcomes and importantly this approach is able to be transferred to other northern basins.

While, this work is still being finalised, the research findings are relevant to a range of end users including:

- State government agencies responsible for water management who will be able to use model results to improve their understanding of the implications for climate change in the Namoi and the potential options for assisting with adaptation of water management options.
- The Catchment Management Authority will be able to use all aspects of the project but more particularly the social component which focused on improved understanding of farmer behaviour and landholder adaption options.

Complimentary to the work of Tony Jakeman and his team, Olive Hood (UQ) is investigating various attempts to collectively integrate natural resource management by the cotton industry, growers, regional bodies, conservation groups and multiple levels of government. While Olive is still yet to complete this PhD project, the initial findings show that state government agencies are significant influencers in the coordination of NRM activity and this raises questions about the sustained attempts in Australian MDB governance to de-centre state administration and integrate multi-scalar administration at the catchment (i.e. sub-state) level. Once complete, this work will provide NRM managers and policy makers with a better understanding of how to analyse the complex arrangements that have evolved in relation to NRM governance and use this information to design more purposeful interventions.

The value of having focussed on this type of research is that policy development frequently happens separately to regions in which it is rolled out. There is a clear need for communities to better understand policy development and for policy makers to better understand the issues in these regions. A more coordinated and engaging process is needed so that industries and regions can not only prepare for the changes that policies will deliver but also participate in its development and take ownership of the outcomes. We hope that this work has started to bridge that divide.

community program
chapter three

Connecting to the Communities

One of the biggest challenges in the Community Program was how to ensure that the research is well connected to the communities in which it is undertaken. The value of social research is often hard for communities to appreciate and also provide direction into when there are so many other more pressing issues. One of the key ways in which we delivered the research the broader community and garnered their input and direction was via the Sustaining Rural Communities Conference.

This conference is unique in that it was established by rural industries, held in a rural community and run specifically to address the needs of rural people. The event gained significant financial and in-kind support from a range of organisations including research organisations, RDA's, CMA's, banks, mining and other community businesses.

Kate Schwager, Community Officer with the Cotton CRC assisted with the delivery of social research. Kate with the Major of Bourke NSW, Andrew Lewis, Geoff wise and Hon John Anderson.

Each year we have been able to attract 250 to 300 delegates from rural communities across Australia. Additionally we have attracted speakers including Tony Windsor MP, Mr Craig Knowles (MDBA Chair), Hon Simon Crean (Minister for Regional Australia) and Mr Mal Peters (Northern Inland RDA Chair).

Most excitingly has been the financial support that the conference has been able to provide to support community groups in implementing specific ideas generated at the conference.

These projects have included:

- Nigyanni Indigenous Corporation who conducted art classes for the remote communities of Gwabegar, Pilliga, Cuttabri and Kenebri as a means of creating opportunities for community gatherings, skill building and cultural pride through art;
- Wee Waa Public School partnered with Wee High School to design, build and race billy carts. Students participated in the project as part of a technology unit and to improve their levels of engagement, goal achieving and to support their transition into year 7;
- An after school homework project for the small community of Burren Junction and done in partnership with Joblink Plus. The program is designed to assist primary student's transition more effectively to high school by assisting them with completing their school work and interacting with older students;
- A grant writing project by Sally Hunter to assist community groups with successful grant writing. Sally worked with nine different community groups to develop their skills in successful grant writing and as a way to look at different business options for running not for profit community groups.





It is these types of people and activities that the conference is able to support which really make change occur in rural communities. The delegates attend because they are passionate about their communities and want to be proactive. The conference provides them with an opportunity to meet like minded people, share and generate new ideas and then provide some financial support to get the ideas into action. This is what makes the conference such a successful event.

Where to next?

Early on in the program development, people within the cotton industry had very little understanding of the science of social research and social researchers had very little understanding of the cotton industry. Many were based in larger metropolitan centres with little or no contact with the industry. Similarly the industry had never really funded social research before.

The Community Program was therefore slow to be established as new networks with industry, community and social researchers had to be formed, each group had to learn to articulate their respective needs, and trust and understanding had to be built. This was difficult in the early years but as research findings began to emerge from the early projects, the true value of social research began to be appreciated.

After 7 years of collaborative research, the Community Program has now got to a stage where it has achieved some significant outcomes including;

- A body of research which has informed and will continue to inform industry and communities on the socio-economic status of cotton communities, industry and community visions for the future, memories of the past and ways in which to better connect;
- Greater industry and community appreciation and understanding of the value of social research. Industry and community bodies are now investing in their own social research using the networks and research built by the Community Program;
- Social researchers directly and genuinely connected with industry and rural communities. The value of this can not be understated;
- The training of 4 PhD students in social research including the industry's first Aboriginal graduate;
- The establishment of the Sustaining Rural Communities conference which will continue beyond the life of the Cotton CRC;
- More meaningful involvement with the local Aboriginal community especially in regards to employment. There have been 5 graduates of the School traineeship program and another 4 through the Catchment Program's traineeship project.

This has been a great and important journey to take at a time when many communities faced significant and rapid change. While the speed of this change can be overwhelming, the efforts of the social researchers and the response they have received from both the industry and community is testament to the growing importance of quantifiable social research. People are genuinely passionate about their communities and industry and well-grounded, reliable social research is an important tool for planning and managing the future for rural communities.

Dallas Gibb

Program Leader 2005-2012

chapter four

product program

Australian cotton growers have a reputation for producing high quality cotton which is sought after in the world market. The key factors that contribute to Australia's position as a producer of premium cotton include the development of premium quality varieties, efficient farming systems, and modern picking and ginning practices. However increasing competition from international producers requires the Australian cotton industry to continually improve its fibre quality and production/processing efficiencies.

To secure it's position on the world stage; the future of the industry is dependent on the continued development of high quality cotton. The industry recognised that to differentiate itself against competition it must continue to produce quality fibre for which customers are willing to pay a premium.

The Cotton CRC's Product Program was established in recognition that the primary competitive advantage that Australian cotton has over its international competitors is the quality of the fibre that it can produce. While Australia only produces 2 to 3 percent of the world cotton, it is the 3rd largest world exporter of raw cotton. Key markets include South East Asia, India, China and Japan. In 2011, China represented more than 70% of Australia's export market.

To drive the industry's competitive advantage for Australian cotton the Product Program targeted six core goals

- Identifying the agronomic impacts on fibre quality and spinnability;
- Preserving fibre quality through improved processing;
- Developing new technologies to facilitate objective definition of fibre characteristics;
- Securing Australia's reputation as a supplier of quality cotton fibre;
- Securing the technical foundation on which an Australian cotton brand can be built;
- Developing complementary options for value adding to irrigation water through aquaculture.

product program
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In establishing these goals, the program's research investments followed the value chain from "Field to Fabric". Research assessed fibre quality at a farm management, ginning and mill level to ensure that quality was not affected across the value chain. To differentiate its fibre quality against international competitors, new research was established on fibre classification and mill processing. It was also recognised that if the industry was to establish a new brand for the promotion of Australian cotton, research activities were needed to support the integrity of any new brand. In assessing alternative high value opportunities for water use, a specific research program was established for developing complementary options for value adding to irrigation water through aquaculture.

In delivering its outcomes The Product has enjoyed partnerships with key research and end-user organisations who collectively have invested \$5.7m of cash and \$8.9m of in-kind into this program area.

On the farm

The production of high quality fibre begins at the farm gate and the decisions that a grower makes in growing cotton. A major investment by the Product Program has been to understand the key agronomic factors that affect fibre development. In recognising the need to reduce fibre traits such as neps and short fibre content (SFC) while improve on fibre length, strength, fineness and maturity, key objectives of this work included:

- Develop an understanding of the degree that crop management impacts on fibre micronaire;
- Improving the understanding of crop management and climate variability on fibre fineness;
- Validate management guidelines to limit neps from the field.

The timing of crop defoliation and picking was recognised as a major factor affecting fibre quality.

Specifically, experiments were undertaken to develop a better understanding to the degree with which fibre micronaire can be manipulated in different climates by measuring the effect and interaction of: variety selection, including in field variety blends; sowing date (impacts of temperature during boll filling); irrigation and nutrient management; harvest management; plant size during boll (fruit) development and overall boll load.

Key conclusions from this work highlighted that variety selection in relation to climatic conditions under which a crop is grown is a key factor affecting fibre quality. This work has led to improved modelling of fibre quality across a range of production conditions and growing regions. The use of improved crop models can assist growers develop risk assessments for fibre quality given set production conditions.

Selected agronomic inputs demonstrated strong correlation between fibre quality, water and nutrition stress and crop yield. The influence of variety selection across different agronomic inputs was less significant with all varieties affected by treatments. Crop boll load, or total fruit load, can have a significant influence on crop yield and quality. For premium quality varieties this affect may be more evident, emphasising the importance of balancing crop vegetative growth and boll load. The assessment of high quality pima cotton crops compared to mainstream upland cotton varieties demonstrated that fibre development within pima crops may occur at a faster rate than in upland crops. The rate of development may influence the overall impact of plant stress on boll fibre quality.

The timing of crop defoliation and picking was recognised as a major factor affecting fibre quality. A key outcome from the research was the development of new crop management practices or tools that improve consistency in the production of quality fibre. These tools will enable growers to estimate fibre quality outcomes before the crop is harvested. One example was the development of a simple crop management tool that considers boll maturity at time of defoliation and enables a grower to predict overall crop micronaire, maturity and fineness.

The key findings from all past and current research on fibre quality have been compiled into a Best Practice Manual for production of fibre quality called **FibrePAK**.

Dallas Gibb, Product Program leader said the promotion of outcomes from this suite of research has led to practice change across the industry.

'In considering fibre quality as opposed to yield alone, growers are now making changes to variety selection, irrigation management to avoid periods of plant stress, crop nutrient management, defoliation management and picker/harvest preparation and management. Ginners now more actively manage lint cleaners on a needs basis in recognition of the impact of cleaning in fibre quality', says Dallas.

'This is very valuable tool particularly for new growers, agronomist, leading farm hands and ginners to better understand the effects they can have on fibre quality.' **Cotton Grower**

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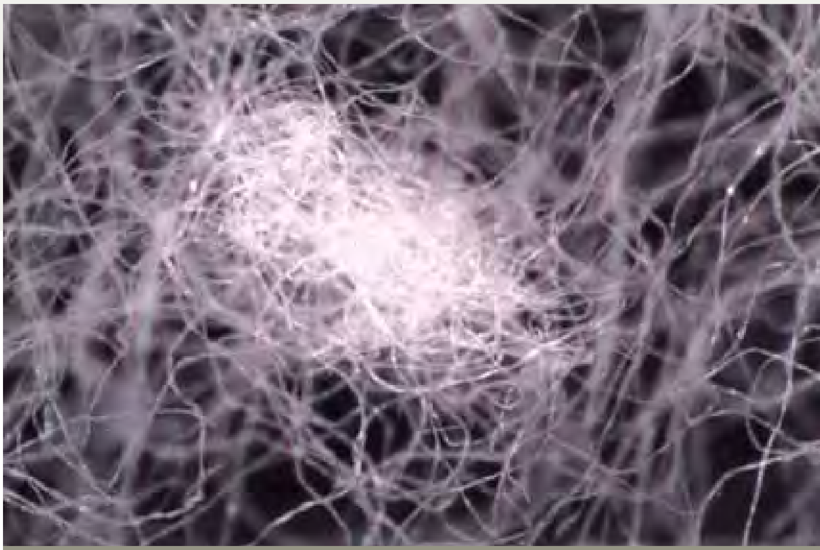

Two key fibre factors that reduced spinning efficiency and the quality of fabric that mills produce are neps (tangles fibres) and short fibre content (SFC). These two parameters while influenced by fibre length and maturity, develop primarily through the mechanical harvesting and ginning of cotton.

In the gin

Ginning research activities aimed to preserve fibre length, while improving ginning efficiency and preventing the overall damage to the fibre as measured through the content of neps and short fibre content. Spinning mills prefer cotton that is long, fine, strong and with a low content of neps (small ball of tangled fibres) and short fibre content (SFC). Primary processing of cotton at the gin is known to have an impact of fibre quality.

Improving ginning processes

The findings from field research on fibre quality were extended beyond the farm gate for the first time by tracing the impact of the quality of cotton produced from the field on final fibre quality post ginning and final yarn and fabric quality. At the ginning level, assessment was focused on how different quality cotton may be influenced by ginning. This work was critical in demonstrating that ginning of immature fibres can lead to a significant increase in fibre neps and SFC.

Neps are not generated naturally by the plant, but result primarily from mechanical working of the fibres. Linking cotton fibre quality and ginning has shown that the more immature the fibre is at harvest the greater the risk that a high level of neps may be developed as a result of ginning. The same was found in regards to fibre fineness. The relationship between fibre maturity and fineness may have a significant impact on final neps content.

Promoting the link between farm and fabric was recognised as a critical gap in existing education programs offered across the cotton industry. The Product Program developed a specialised training course called “Cotton Field to Fabric”. The only course of it type in Australia, the program is targeted at having growers, merchants, mills owners, fabric buyers and brand-owners all meeting at one location to gain a greater understanding of the entire cotton value chain. Cotton Field to Fabric training course has been presented 11 times since 2005 with a total of 266 participants”

Moisture assessment and management is a fundamental problem in the ginning process. Siroduct was designed to measure the moisture of fast moving seed-cotton and/or lint during ginning. Moisture duct light sensor ready for installation

Cotton in the siroduct moisture sensor is a spectacular sight.

In comparing the mechanical damage caused to a fibre through picking and ginning, it was shown that the use of lint cleaners produced the greatest impact of both neps and SFC. The ginning of immature fibres produced an exponential increase in neps, highlighting the need for greater assessment of fibre quality before ginning and also the importance of effective use of lint cleaners.

As it was recognised that lint cleaning can have a major impact on quality, a targeted research program was developed to evaluate how the lint cleaner may be altered to minimise its negative impacts on fibre quality. This work led to the development of a modified lint cleaning device (MLC). The device may be cost-effectively retrofitted to existing lint cleaners. Commercial scale evaluation of the MLC demonstrated improvements in fibre length (2%), length uniformity (2%) and a decrease in SFC (12%) compared to current commercial lint cleaners.

Moisture assessment and management is a fundamental problem in the ginning process. Cotton is only able to adsorb up to 7% moisture. Research outcomes demonstrated that as the cotton dries to levels less than 6% it becomes more prone to damage leading to a reduction in fibre length, higher SFC and neps levels. In order to address this problem of maintaining moisture at the optimum level, there was a need to establish an accurate method to measure fibre moisture while ginning.

Cotton CRC research targeted new methods for assessing moisture in the gin, resulting in the development of a new patented moisture sensor called, SiroDuct. The technology is designed to measure the moisture of fast moving seed-cotton and/or ginned lint during ginning. The sensor utilises a large scale capacitor and light detectors to measure the moisture of cotton material as it moves from one part of the gin to another.

The new sensor was assessed throughout commercial ginning trials and demonstrated that SiroDuct is more effective than existing fibre moisture devices. While the technology aims to improve moisture management in ginning, additional benefits included a reduction in total energy use in the gin as real time moisture monitoring enabled more effective management of dryers and humidifiers.

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Reducing Contamination

Contamination, even if it is a single foreign fibre, can lead to the downgrading of yarn, fabric or garments to second quality or even the total rejection of an entire consignment and is thus a very important fibre parameter. While Australian cotton had traditionally received premiums for low contamination, a 2005 International Textile Manufacturers Federation contamination survey showed an increase in the number of contaminated Australian cotton bales delivered to overseas spinning mills. Contamination represents a significant cost to spinning mills and this has led them to implement methods to cope with contamination.

Manual removal of contaminants from cotton before release to spinning mill (India).

A key objective for the Cotton CRC was to reduce the level of contamination in raw cotton by 50%. To achieve this objective an extensive monitoring program was conducted in collaboration with local ginners and international mills to accurately measure all contaminates. The major contaminants found in cotton delivered to the gin were metallic pieces from harvesters, module builders and from transportation of cotton modules to the gins. Items causing contamination included module ropes, plastic bags, grass, timber, grease and oil (mainly due to hydraulic oil), fabric (rags and cloth) and tarp from module covers.

At the mill, the major contaminant found in Australian cotton compared with other cotton sources were pieces of cloth from either woven or knitted rags or clothing in various colours consisting of both cotton and polyester.

Through this monitoring program, the Cotton CRC developed best management practices for picking and bale management post ginning. This was combined with an extensive cotton quality management education program. The combination of these activities has achieved the target of a 50% reduction in contamination. Australian cotton now has a reputation for the lowest levels of contaminated cotton.

New round bale modules.

Dallas Gibb said *'the awareness and proactive response by the industry resulted in a 50% drop in contaminates in Australian cotton and confirming its status as one of the least contaminated sources of cotton worldwide as measured by the ITMF Contamination Survey.'*

It is estimated that Australian growers now receive a $20 to $25 premium per bale base due to the low level of contamination. This premium is estimated to be worth more than $80 million per year to the industry.

In recognising the quantum change in picking technologies that has occurred in the industry since 2009, new research was initiated to develop automated contamination detection systems. The new picking systems produce round modules that are wrapped in plastic. This plastic, if it was to enter the gin would result in a significant contamination risk.

The best opportunity to detect and remove contamination is early in the ginning process. Through the use of existing high-speed lighting and colour image sensors, a new prototype contamination sensor device has been developed for use in gins. The device has been developed to detect yellow and blue plastic particles but may also be used to detect other contaminates. Development of the technology has occurred through collaboration with Australian ginner's and commercial partners.

In the classing room

Assessment into the key fibre properties required by mills for the production of high quality yarns has highlighted that outside the traditional fibre characteristics of length and strength, fibre fineness and maturity are key factors affecting mill efficiency. The fibre properties least preferred for the production of quality yarns are neps or a collection of tangled immature fibres, and the level of short fibre content (SFC). The higher the level of neps and SFC within the raw cotton used by a mill, the larger the negative impact on mill efficiency and the higher the level of wastage.

The cost of raw cotton may contribute up to 60% of the overall cost for a spinning mill in the production of a fabric. For this reason international mills that produce premium fabric pay particular attention to the quality of the cotton they purchase. In the past however, they have lacked the means to measure the two key fibre quality attributes of maturity and fineness objectively.

Objective measurement of key fibre attributes is now commonplace for the marketing of cotton. Mills either rely on the cotton traders providing objective fibre data with each cotton shipment, or they test the cotton once it has been delivered. The most common instrument used for fibre testing is the High Volume Instrument (HVI).

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HVI measurements provide an accurate assessment of fibre length and strength, but only combine the properties of fineness and maturity into one single measurement called micronaire. However, micronaire is an indirect measurement related to the specific surface area of the specimen; a measurement that results from a combination of fineness and maturity. It does not indicate fineness or maturity. Micronaire is well recognised as a limited measurement for mill quality control purposes.

Dr Stuart Gordon, lead researcher for the assessment of fibre maturity with CSIRO Material Science and Engineering says that

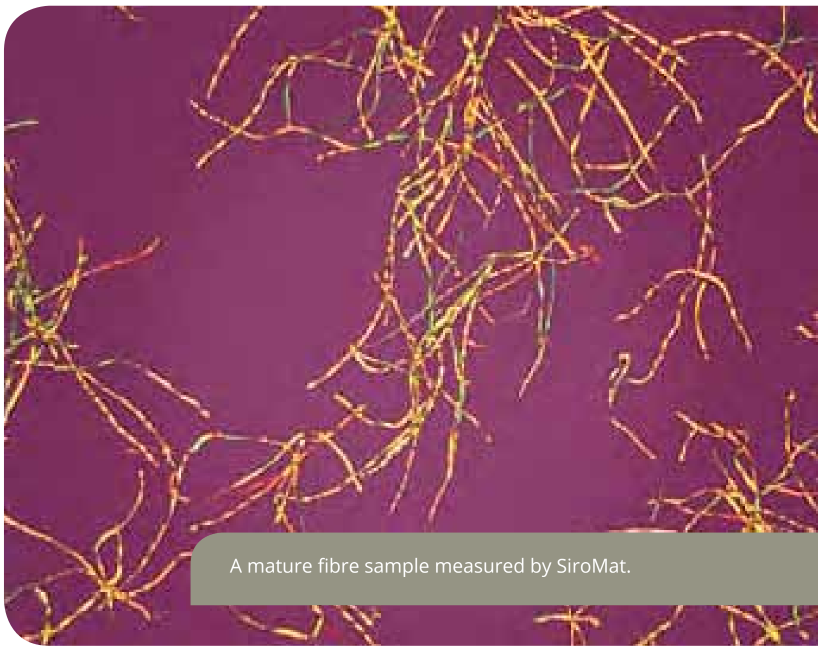
'from a commercial perspective, use of micronaire means that fine, mature fibres, which are desirable, can be incorrectly classed as similar to immature course fibres. This incorrect classification may lead to inappropriate selection of cotton by a mill in the production of yarns and fabrics.'

'Development of objective measurements for fineness and maturity will enable Australian cotton to have greater differentiation in the market and to attract and secure higher premiums'.

Whilst there are a number of methods for measuring fibre maturity and fineness, until recently no one method has been able to do so accurately and with the speed requirement for classing purposes. The Cotton CRC invested in the development of two technologies, SiroMat, which measures fibre maturity and Cottonscan, which assesses fibre fineness. These instruments create fast and accurate test methods for breeders, merchants and spinners alike to manage fibre linear density and fibre maturity.

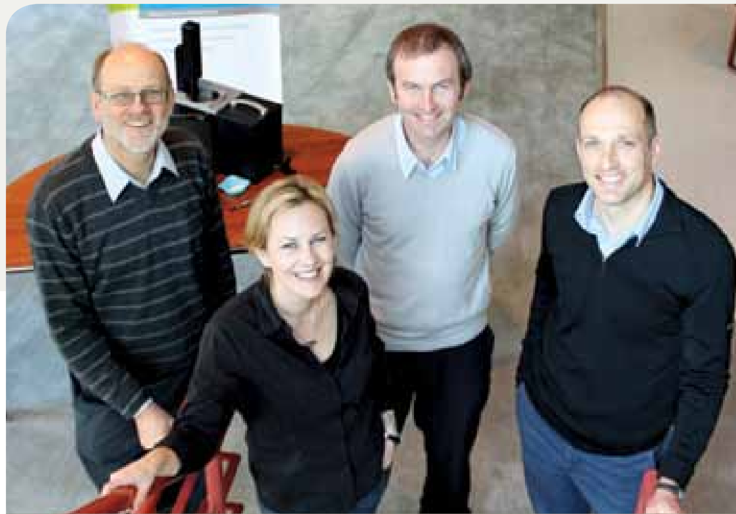
SiroMat became the first measurement to directly measure fibre maturity. The technology also provides for the first time a distribution analysis of fibre maturity to allow an accurate assessment of the variability of maturity across a sample. This information can be used to determine the variability of a fibre maturity within a new variety and also within the final yarn and fabric. Use of the instrument by mills has shown that an accurate assessment of maturity can greatly improve the efficiency of yarn and fabric processing techniques such as dye uptake.

SiroMat technology centres on the use of automated polarized light microscopy to assess individual fibre samples.



A mature fibre sample measured by SiroMat.

Cottoncope technology is the result of combining SiroMat and Cottonscan together. Cottonscope provides an accurate and meaningful measurement of fibre maturity and fineness - which are considered the most important properties by spinning mills across the globe.



In recognition of the innovation involved in Cottonscope, the instrument was a finalist in both the 2011 Australian Museum Eureka awards and the Engineers Excellence Awards. Cottonscope Team: L to R, Geoff Naylor, Nicole Phair-Sorensen, Stuart Lucas and Stuart Gordon.

With the Cotton CRC investments targeting the development of SiroMat, the Cotton Research and Development Corporation (CRDC) was able to focus its investments on refining the assessment of fibre fineness. These activities lead to the development of the instrument called Cottonscan which provided the world's first direct measurement technique for fibre fineness.

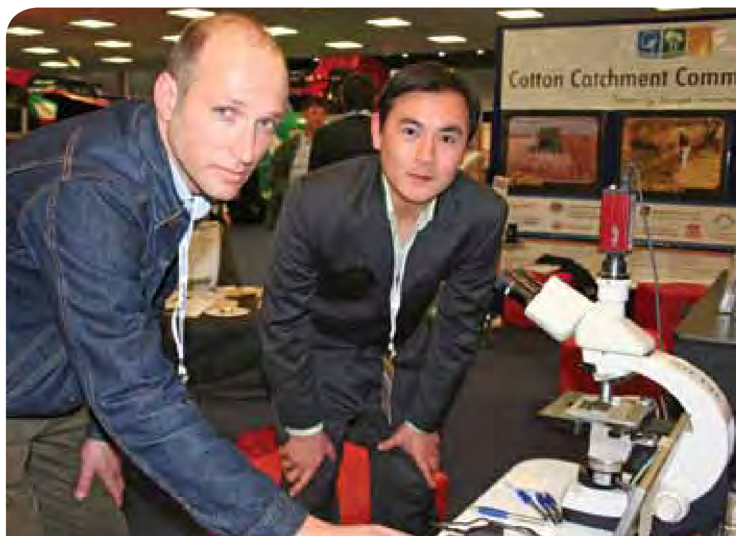
BSC Electronics, commercial partners licensed by the Cotton CRC, combined the novel fibre measurement technologies of SiroMat and Cottonscan into one machine called 'Cottonscope'.

Dr Eric Hequet Associate Director International Cotton Research Centre Texas Tech University said

'Until a recent period and in spite of the importance of maturity and fineness for the textile industry, there was no direct or indirect measurement method that was both fast and reliable. The Cottonscope is currently the best candidate to fill this void.'

In streamlining the two technologies and employing faster image processing and data analysis BSC Electronics have developed a final product that may be used as a regular tool for assessing fibre quality and be complementary to commercial HVI testing systems. The technology was released in 2010.

BSE Electronics continue to promote the technology to local and international classing houses and mills. To optimise benefits for industry, cotton merchants may use Cottonscope to offer an additional objective fibre measurement to mills and dyeing houses to further differentiate Australian cotton from competitive cotton types.



Dr Stuart Gordon CSIRO and Hy Hwang of BSE Electronics.

In the mill

International mill surveys have shown that Australian cotton is used in the production of 40 Ne to 60 Ne count yarns and fabrics. However, as the quality of cotton from competing countries improves, it is expected that price premiums for production of > 40Ne yarns will be reduced leading to downward pressure being placed on the price for raw cotton that is used in this market. The opportunity for Australian cotton is to improve its quality to a level where mills can efficiently produce higher quality 70 Ne to 100 Ne yarns. Currently little Australian cotton is use for such fine count yarns.

In the mill, various types of cotton are blended depending on the quality of fabric being developed. Australian cotton is often used alone or with other lower grade cottons. In making their cotton purchasing decision, mills require an accurate assessment of what fibre properties can be used to produce a set quality yarn.

Moving beyond the research facilities in extending the knowledge of how fibre properties impact upon final yarn properties, the Cotton CRC established research to collaborate with international mills to develop novel spinning prediction software, named "Cottonspec". The purpose for such a system was to increase the use of Australian cotton in the production of premium yarns, and thereby increase demand for Australian premium cotton.

To help mills improve their efficiency and use of Australian premium cotton types, the "Cottonspec" system allows mills to improve the selection of cotton for production of specific yarns and fabric. Leading researcher Dr Shouren Yang says that

'Cottonspec has the capacity to improve the classification of Australian cotton by linking cotton fibre quality with yarn quality with theoretical modelling. This will inturn provide opportunities for Australian cotton to be marketed against specific mill demands based on the quality of yarn they aim to produce'.

"Cottonspec", has been commercially assessed across major mills in China. This is the first time Australian cotton researchers have collaborated with mill customers from initial concept to commercial reality.

Cottonspec trials - Spinning frame showing the spinning of high quality fine count yarn in Mill No. 1 using 100% Australian long staple Sicala 340BRF.

The development of Cottonspec is expected to provide a valuable tool for selected quality mills by providing a range of commercial advantages. These include:

- Management of cotton purchases – cotton selection based on yarn orders;
- Management of laydown – optimise laydown for related yarns;
- Management of spinning – QA measure for operations.

While not providing direct benefits to growers, indirectly the aim of the technology is to create demand-pull for higher quality Australian cotton. Such cotton would be used by the mills to improve efficiency in producing quality 70Ne + yarns or higher. Feedback from collaborating mills have emphasised the value of the technology:

"Applications of the software will play active roles in reducing the mill's production costs and improving their production efficiency."

"Applications of Cottonspec will help spinning mills to improve the efficiency of cotton laydown design"…

"This software is a useful cotton fibre and yarn quality management tool"

The technology will be promoted across Australian cotton merchants to assist in the marketing of Australian cotton.

Growing more than cotton

As well as adding value to Australian cotton, the Product Program also investigated the opportunity for intensive aquaculture to be used within on-farm water storages. This work focused on the farming of silver perch. The basis for this work was to provide an alternative source of high value income for cotton growers that optimised existing infrastructure and water resources.

Aquaculture is the fastest growing food-producing industry in the world. However, water use, available land, infrastructure and production costs are just some of the problems that hinder aqua-cultural expansion. The Cotton CRC recognised the market growth of aquaculture and saw an opportunity for the development of intensive aquaculture to be used within on-farm water storages.

David Foleys PhD research project focused on how to boost silver perch availability and lower production costs by using cage culture combined with the water resources currently available in cotton and other irrigation industries.

Australian freshwater silver perch is a high quality seafood with an abundance of healthy omega 3 fatty acids. It has a medium to strong flavour, relatively few bones and firm white flaky flesh.

product program
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'Cotton farms contain a number of water storages and with increasing pressure to ensure the sustainable use of water in irrigation farming, aquaculture may be a means of returning a higher value from water used for irrigation', said David.

The project aimed to find the optimal conditions for cage production and looked specifically at stocking density, feeding, production strategies, disease management and cage design.

The study demonstrated that through appropriate cage design and management, silver perch survival and growth rates could be significantly improved over open pond-based systems.

As part of David's research he developed a new cage design and dieting techniques to optimise production and wrote the Best Practice guidelines for Silver Perch production in on-farm storages. David's PhD was supported by the Cotton CRC and the University of New England. Additionally he also won the Ocean Wave's Seafood prize for designing an off-shore abalone cage

'Given the large number of on-farm water storages used across the irrigation industry the outcomes have demonstrated that with appropriate investment in infrastructure a real opportunity exists for the establishment of a sustainable seafood industry, based in silver perch, within regional NSW and Queensland', says David.

A rep to protect

The reputation of Australian cotton is built on the industry's ability to produce consistently high quality cotton. This has been achieved through its development of premium cotton varieties, use of efficient farming systems, modern picking and ginning practices. All of which are supported by significant investments in research and development and the industry's *my*BMP program. The Product Program represents the coming together of the industry's efforts in establishing its world class reputation and capacity to maintain that reputation into the future. These efforts guarantee that the cotton that leaves Australia's shores is of the highest quality.

The Cotton CRC developed the Product Program with the primary aim to ensure that growers have the capacity to produce cotton of the highest quality and that these quality attributes are preserved across the value chain. Working beyond the traditional boundaries of industry research, the Product Program extended it investments to work with international mill partners in the development and assessment of technologies that target the use of premium Australian cotton.

From the beginning, the Product Program fostered collaborative research with applied outcomes through partnerships between researchers, industry, end users and government departments. This approach ensured the program identified and focussed on issues most meaningful to the cotton industry, and gave environmental research a fresh lens through which to recast conceptual models and engage not only with growers, but also for the first time with key international mills customers.

The research and commercial products developed in the Product Program have already, and will continue to make a significant contribution in enabling the industry to produce high quality consumer- preferred cotton. They include the :

- Development of new fibre measurement technologies, (Cottonscope) that enables the industry to differentiate its cotton more effectively;
- Development of the modified lint cleaning device - MLC;
- Development of novel moisture monitoring technology for use within cotton gins – Siroduct
- Development of mill spinning software technology (Cottonspec) that improves the use of Australian cotton within mills for the production of premium yarns and fabrics;
- Development of BMP programs across the value chain from crop management through to ginning and classing of cotton as well as guidelines for Silver Perch production in on-farm storages;
- Development (prototype) of new fibre contamination sensor technology for use in gins.

The industry now has the necessary tools and resources for it to continue leading the world in the production of high quality cotton and that is a significant legacy for the program and the Cotton CRC.

Through combining the research outcomes developed at the farm, gin and mill level the Cotton Catchment Communities CRC has delivered on its goal to "enable the industry to produce high quality consumer-preferred cotton". The achievement of this outcome places the Australian cotton industry in an ideal position to increase its international competitiveness and reputation as a supplier of premium cotton.

Yvette Cunningham

chapter five

education and training program

A dynamic education and training program is essential in attracting and retaining the best new students and scientists for the long-term benefit of the australian cotton industry.

The Australian cotton industry is recognised as a leader in the primary industry sector, in terms of both innovation and the industry's uptake of new technologies. This success can be attributed largely to the highly trained and skilled professionals who work in the industry, coupled with continued investment in research and development.

Rural and regional Australia however, is experiencing a shortage of skilled science professionals to meet industry demand. The Cotton CRC sought to address these shortages through its Education and Training efforts. The Education and Training focus has been on providing educational opportunities which offer a flexible path for skills and knowledge development at all levels of the industry through:

- a postgraduate program (PhD and Masters);
- postgraduate cotton courses;
- various undergraduate activities;
- up-to-date specialist short courses and vocational training for cotton consultants, agribusiness, cotton growers and their staff;
- promoting science and agriculture in schools.

In addition to this, the Cotton CRC Development and Delivery Team have delivered informal training opportunities across a broad range of research disciplines throughout cotton growing regions. Grower-focused short courses and focus groups have become a recognised platform for engaging growers. A wide range of university level education activities have been carried out, with the courses promoting complimentary approaches to production and natural resource management, using participatory and action learning methodologies.

Yvette Cunningham

Program Leaders

Yvette Cunningham 2009 – 2012
Letitia Cross 2006 – 2009

Postgraduate Students

The Cotton CRC has awarded 62 postgraduate scholarships over the past seven years. With 35 PhDs currently completed, 11 submitted for examination and 14 due for completion beyond June 2012 *(Table 1)*. These research scholarships have spanned the four CRC research programs. Many of the students worked on projects that were integrated into larger Cotton CRC-supported research described elsewhere in this book. As well as PhD scholarships, the postgraduate program also awarded two scholarships for Masters by Research and supported 15 honours students. PhD scholars were also eligible for scientific exchange scholarships, which supported travel in Australia or overseas which could benefit their research *(see below).*

A full PhD scholarship included an annual stipend of $26,000, with an additional $6000 for operating funds. In some cases students have already been awarded various University and APA scholarships and the Cotton CRC provided additional funds to take their stipends to the value of a full scholarship.

Yvette Cunningham, Adoption, Education and Communications Program Leader said

'this CRC stood out from previous CRC's due to the ambitious targets set around graduating 50 postgraduate students. Yet despite the drought and competing industries we managed to have a total of 77 postgraduate and honours projects within this CRC. This is quite an achievement.'

"The unique nature of the Cotton CRC saw the combination of production, environmental and social postgraduate research to take place within an industry context. The broader and multidisciplinary scope allowed research projects to take place that would not have been able to occur without the Cotton CRC" Says Yvette.

A key feature of the Cotton CRC postgraduate program was its collaborative learning approach. Supervisors and students adopted a team-based approach to research design, ideas were developed in a cooperative manner and, as with all research projects at the Cotton CRC, key participants and stakeholders were heavily involved.

The Cotton CRC worked hard to make students feel part of its research community. This was achieved by ensuring students had adequate opportunities to present their work at annual Science Forums and the bi-annual Australian Cotton Conference. Students were also given opportunities to network with world renowned researchers and other students. Additionally, the Education and Training Program coordinated a number of workshops and professional development courses for Cotton CRC students, including science communication, IP management, leadership and thesis writing workshops. Dedicated industry tours also exposed students to all aspects of the cotton industry from the agronomic/irrigation practices on-farm through to the picking, ginning and spinning processes. As a result, postgraduate students, regardless of which research discipline they were aligned with, understood the role their research played in an industry-wide context.

The breadth of the Cotton CRC's multidisciplinary research is most apparent in the range of postgraduate projects undertaken over the last 7 years. While many of these are discussed further in their respective program areas, the following is just a snapshot of the diversity of the Cotton CRC postgraduate research.





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Table 1: Postgraduate Student List

1.	**ADRIANA NAJAR RODRIGUEZ**	PhD	The cotton aphid *Aphis gossypii* in Australia: petroleum spray oils, endosymbiotic fauna and host-plant interactions	UQ	Awarded
2.	**MICK ROSE**	PhD	The environmental benefits of constructed wetlands on cotton farms: pesticide remediation	USYD	Awarded
3.	**DEREK COLLINGE**	PhD	Transformation and gene silencing Technologies to control *Helicoverpa armigera*	ANU	Awarded
4.	**JEFF WERTH**	PhD	Weed resistance modelling for glyphosate tolerant cotton	UA	Awarded
5.	**STELLA LOKE**	PhD	Diversity of VAM fungi in soil health	USYD	Awarded
6.	**INGRID RENKEN**	PhD	Role of native vegetation in harbouring beneficial insects and reducing insect pest damage in cotton	UNE	Awarded
7.	**LEONIE WHIFFEN**	PhD	Arbuscular mycorrhizal fungi and carbon sequestration in soil	USYD	Awarded
8.	**KYLIE DODD**	PhD	Characterizing the plant and soil interactions that affect the growth and nutrition of cotton (*Gossypium hirsutum* L.) In sodic vertosols	UNE	Awarded
9.	**JAMAL NEJEM**	PhD	Coupled streamflow and groundwater modelling for improved irrigation allocation estimates	UTS	Submitted
10.	**CHRIS VANAGS**	PhD	A geophysical and hydrological investigation of palæochannels in Northern New South Wales	USYD	Awarded
11.	**FRANCIS KARANJA**	PhD	Ecosystem service provision from natural resource management interventions in the Gwydir catchment, north-western new south wales: spatial bio-economic evaluation at catchment, district and farm scales	UNE	Awarded
12.	**GUY ROTH**	PhD	Economic, environmental and social sustainability indicators of the Australian Cotton Industry	UNE	Awarded
13.	**SUSAN LUTTON**	PhD	Aquatic biodiversity and the ecological value of on-farm water storages on irrigation farms	Griffith Uni	Awarded
14.	**LISA YU-TING LEE**	PhD	Efficient water allocation in a heterogeneous catchment setting	USYD	Awarded
15.	**JASON MOULYNOX**	PhD	Bio-control agents for managing black root rot in Australian cotton	UNE	Awarded
16.	**JAMIE HOPKINSON**	PhD	Managing cotton aphids with parasitoids	UQ	Awarded
17.	**JENNIFER WHAN**	PhD	Investigation of the effects of silicon application on the resistance of cotton to *Fusarium oxysporum* f.sp. *Vasinfectum*	UQ	Awarded
18.	**NICOLA COTTEE**	PhD	Thermotolerance of cotton	USYD	Awarded
19.	**XIAOJUAN WANG**	PhD	Phosphorus acquisition characteristics of cotton (*Gossypium hirsutum* L.) compared with other crop species	La Trobe	Awarded
20.	**DEBBIE BURGIS**	PhD	Optimising river flow management for environmental and economic sustainability in the lower Gwydir River	UNE	Withdrawn
21.	**KATHRYN KORBEL**	PhD	Robust and sensitive indicators of groundwater health and biodiversity	UTS	Continuing

22.	**SUE POWELL**	PhD	Analysis and modelling of the flood pulse and vegetation productivity response in floodplain wetlands	ANU	Awarded
23.	**FLORIS VAN OGTROP**	PhD	Modelling rivers in semi-arid Australia: Temporal and spatial aspects	USYD	Awarded
24.	**JAMES HEREWARD**	PhD	Is the source of mirids in cotton derived from local dispersal or long distance migration?	UQ	Submitted
25.	**DAVID PEROVIC**	PhD	Do landscapes surrounding cotton crops significantly affect conservation biological control within crops?	CSU	Awarded
26.	**RHIANNON SMITH**	PhD	Biodiversity and ecosystem services associated with remnant native vegetation in an agricultural floodplain landscape	UNE	Awarded
27.	**BAOQIAN LU**	PhD	Thresholds and mechanisms of survival for Bt-susceptible *Helicoverpa* spp. living on Bollgard II® cotton	UNE	Awarded
28.	**SAM ALOMARI**	PhD	Molecular analysis of proteobacterial communities in soil under cotton- Microbes contribute to soil at least three key functions for plant growth and development	USYD	Withdrawn
29.	**DAVID FOLEY**	PhD	Performance, welfare and production strategies for the cage culture of silver perch (*Bidyanus bidyanus*)	UNE	Awarded
30.	**ANDREW MACCALLUM**	PhD	Development of a 3D geological mapping and database interface to support interconnected groundwater and surface water management	UNSW	Continuing
31.	**CHRISTOPHER CARR**	PhD	Optimising the establishment, persistence and impact of Trichogramma in NSW	UNE	Continuing
32.	**DAWIT BERHANE**	PhD	Transmission losses in semi-arid rivers, a loss or a gain	USYD	Submit
33.	**PETER BERNEY**	PhD	Gwydir Wetlands: impacts of water regime and grazing on floodplain wetlands	UNE	Awarded
34.	**WARREN CONATY**	PhD	Temperature-time thresholds for irrigation scheduling in precision application and deficit furrow irrigated cotton	USYD	Awarded
35.	**ANNA GREVE**	PhD	Detection of subsurface cracking depth through electrical resistivity anistropy	UNSW	Awarded
36.	**PAUL COOP**	PhD	Detection of monolayers	UNE	Awarded
37.	**DONNA MOODIE**	PhD	Inclusive engagement and development: an indigenous perspective of community, business and sustainable development	UQ	Continuing
38.	**JAMES QUILTY**	PhD	Organic amendments and soil health in broadacre irrigated cotton production systems	USYD	Awarded
39.	**JOHN BENNETT**	PhD	Combating sodicity in the Lachlan and Macquarie Valleys of New South Wales	USYD	Awarded
40.	**MARCELO PAYTAS**	PhD	Early water stress on growth, development and yield of high retention cotton	UQ	Awarded
41.	**CHRIS ANDERSON**	PhD	Diseases of cotton IX	NSWDPI	Continuing
42.	**TODD GREEN**	PhD	Ecology of fleabane (*Conyza* spp.)	UNE	Awarded
43.	**BROOKE SAUER**	PhD	An assessment & evaluation of current and proposed precision agriculture tools; commercial broad acre applications to the cotton and grains industry	UNE	Continuing

44.	**MEREDITH ERRINGTON**	PhD	Nutrient redistribution within cotton plants	USYD	Submitted
45.	**JAY DHUNGEL**	PhD	Field aspects of multigation - fertigation and oxygation	UCQ	Submitted
46.	**MANOUCHEHR TORABI**	PhD	Optimizing oxygen delivery in subsurface drip irrigation	UCQ	Awarded
47.	**MEGAN GOOD**	PhD	Managing invasive native scrub in the endangered ecological community of coolibah-black box woodland of the northern riverine plains in the darling riverine plains and brigalow belt south bioregions - a case study in t he lower namoi	UNE	Submitted
48.	**MITCHELL BURNS**	PhD	Catchment scale risk assessment for agrochemicals	USYD	Submitted
49.	**OLIVER ROBERTSON**	PhD	Healthy cotton catchments: integrating biodiversity, ecosystem services and landscape pattern for sustainable production	UQ	Submitted
50.	**YUCHUN JI (SARAH BENNETT)**	PhD	Groundwater modelling projects: Coxs Creek - Developing stochastic deep drainage surfaces for the Coxs' Creek catchment	USYD	Submitted
51.	**GETACHEW ALI**	PhD	Genetic factors involved in pathogenicity of *Thielaviopsis basicola* towards cotton	UNE	Submitted
52.	**HABIBULLAH BAHAR**	PhD	Integration of a predator and a pathogen with transgenic Bt cotton in controlling *Helicoverpa armigera*	UNE	Awarded
53.	**RICHARD KOECH**	PhD	Automation and real time control of furrow irrigation	USQ	Submitted
54.	**TIM MCLAREN**	PhD	Improving P and K fertilizer use efficiency in depleted or sodic vertosols	UNE	Continuing
55.	**BRENDAN GRIFFITHS**	PhD	Addressing agronomic constraints in irrigated wheat production in the northern grain regions	UNE	Continuing
56.	**STEPHEN YEATES**	PhD	Irrigated cotton in the tropical dry (winter) season	CSIRO	Awarded
57.	**OLIVE HOOD**	PhD	Collective NRM and Socio-economic scenarios in cotton communities	UQ	Continuing
58.	**ALISON WILSON**	PhD	Economic-environmental water trade-offs in the Namoi under climate change & variability	UWA	Continuing
59.	**MADELEINE HARTLEY**	PhD	The legal framework for economic-environmental water trade-offs in the Namoi under climate change & variability	UWA	Continuing
60.	**DOMINIC CROSS**	PhD	Better management of cotton refuges within the BMP framework	USYD	Continuing
61.	**KATIE BROUGHTON**	PhD	Improving prediction of cotton growth and production in a changing climate (post-graduate scholarship application)	USYD	Continuing
62.	**KRIS LE MOTEE**	PhD	Ecology of *Helicoverpa punctigera* revisited: implications for Bt resistance	UNE	Continuing
63.	**LEAH MACKINNON**	Masters	Microbats in changing cotton production landscapes: a case study from the Namoi River in New South Wales, Australia	CSU	Awarded
64.	**KEVIN BAGSHAW**	Masters	Improving gin stand performance to benefit Australian cotton	USQ	Awarded
65.	**ALISON DEVEREUX**	Masters	Quantifying effects of maize rotation on soil quality and nutrient availability on cotton growth and yield	UQ	Withdrawn

Nicola Cottee, USYD

James Quilty

Leah MacKinnon's Masters project showed that microbats contribute to reductions in cotton pest moth *(Helicoverpa* spp.*)* populations by both direct predation and interruptions to reproductive activities resultant from avoidance behaviour. Contributions to pest management and microbat tree-hollow roost requirements could provide economic and environmental incentives for improved remnant native vegetation management.

PATTERNS IN PLANT COMMUNITY AND POPULATION DYNAMICS OF COOLIBAH WOODLANDS

Megan Good

Coolibah, a native floodplain eucalypt tree commonly found on cotton farms, regenerated densely in northern NSW and southern Queensland following floods in the 1970s. Megan Good's PhD project, aimed to investigate the community and population dynamics of Coolibah woodlands in order to quantify the effects of dense regeneration on pasture biodiversity and the role of dense regeneration in biodiversity conservation and woodland persistence in the landscape.

Over a three-year period, Megan found that there were more ground storey plants in patches of dense regeneration when compared with adjacent grasslands and, in general, ground storey plant community composition was similar throughout the landscape, irrespective of tree density. Analysis of tree size distributions in remnant woodlands and dense regeneration revealed that dense regeneration occurs where large trees are sparse.

Megan found few, or no, Coolibah seedlings in remnant woodlands where mature tree density was higher than 22 stems per ha. This indicates that dense regeneration outside of remnant woodlands might be vital for the persistence of Coolibah woodland in the landscape. She also found that seasonal conditions and insect herbivory affected tree seedling survival more than competition from grasses and that grasses were actually vital for Coolibah seedling survival.

These results suggest that dense regeneration occurs sporadically in response to rare climatic conditions, has no negative effects on plant diversity or composition and will self-thin with time. The persistence of Coolibah woodlands in the landscape is dependent on episodes of dense regeneration and all stages and structural states of Coolibah woodland are important.

As a result of Megan's research, land managers and CMAs in these areas now know more about the natural dynamics of Coolibah trees and the conditions required for regeneration.

Megan says that without the financial assistance provided by the Cotton CRC and CMA's she would not have been able to undertake her PhD.

"The CRC was really interested in and valued my research into biodiversity and plant ecology" she says.

Megan's PhD was supported by the Cotton CRC University of New England, Namoi CMA and Central West CMA.

KEEPING GENETICALLY MODIFIED TECHNOLOGY SAFE

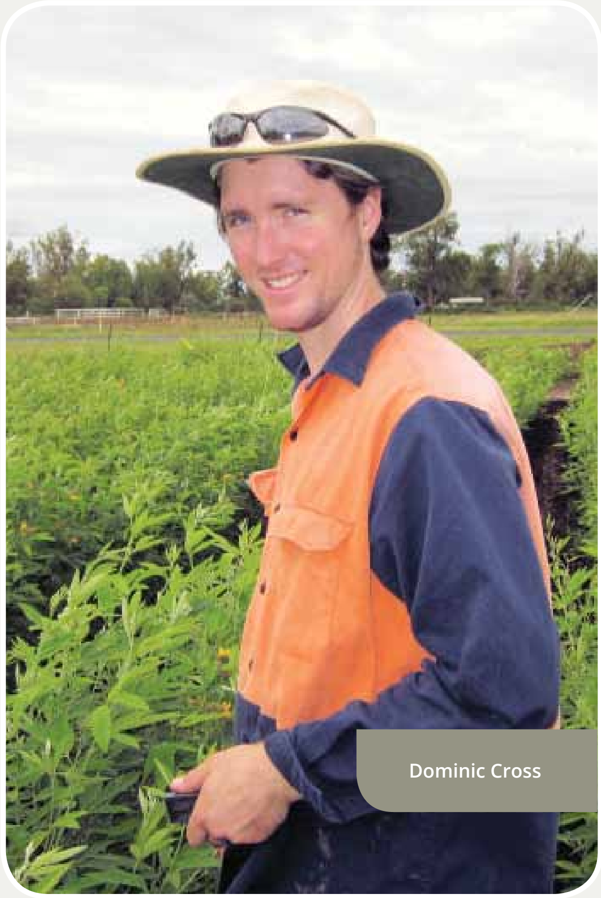
The potential for *Helicoverpa armigera* and *H. punctigera* pest populations to become resistant to *Bt* cotton has been a topical issue in the past few years. In order to maintain susceptibility, refuges of unsprayed non-*Bt* cotton or pigeon pea are planted with *Bt* cotton so that susceptible populations dilute any acquired resistance, maintaining the effectiveness of *Bt* cotton. PhD student, Dominic Cross, is investigating the most efficient refuge to keep resistance at bay. Planting a crop with no direct commercial value in order to produce high numbers of invertebrates can appear counterintuitive to growers, so quantifying and improving the efficacy of refuges is necessary to maintain industry support.

While higher densities of *Helicoverpa* larvae in refuges should result in higher populations of *Bt*-susceptible moths, predators, disease and parasitoid populations would also increase and are likely to place an upper limit on production. Consequently, larger numbers of larvae may result from fewer moths. Part of Dominic's research is identifying whether there is a point at which the density of *Helicoverpa* spp. in the crop causes the population to crash, and whether this point varies between refuge types.

Dominic's project will determine the best management strategy for refuges in cotton to ensure maximal output of *Bt* susceptible moths. From a practical perspective, the information gained will enable growers to be confident that they are getting the best biological benefit from their refuges via the most cost-effective means.

From a biological perspective, the project will examine the effects of high herbivore numbers.

Dominic's PhD project is supported by a Cotton CRC and CRDC scholarship and the Faculty of Agriculture, Food and Natural Resources, University of Sydney.



Dominic Cross

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GROUNDWATER GOODNESS

Groundwater dependent ecosystems (GDEs) are ecosystems that, at least periodically, rely on groundwater to maintain their ongoing health, structure and function. The dependence of GDEs on groundwater ranges from intermittent (drawing on groundwater in periods of drought), to total, continual reliance. Groundwater ecosystems, although still largely understudied in Australia are home to a unique assemblage of invertebrates (stygofauna) and microbes that are highly adapted to life under the earth's surface. These biota are believed to provide ecosystem services essential in retaining groundwater quality and flow within aquifers, thus the maintenance of these ecosystems is important. The concept of groundwater health and the factors influencing groundwater biota are central to Kathryn Korbel's PhD research which examines the distribution of groundwater biota in relation to agricultural practices in the Gwydir and Namoi catchments.

Kathryn is carrying out her PhD with the University of Technology Sydney, investigating ecosystem health and its assessment in connected aquifer ecosystems and is using this research to develop a framework for assessing ecosystem health. Kathryn identified Tier One and Two indicators of a healthy groundwater ecosystem that, together, can be used to generate a multi-metric index of groundwater health.

To date, Kathryn has discovered a number of new macroinvertebrate species and she has identified those biota which are robust in assessing water quality and groundwater health. As part of her PhD, she is developing a photographic library of the stygofauna she collects and which will serve as a valuable reference tool for inclusion in the final toolbox product.

Kathyrn said her work will produce a 'toolbox' of indicators that, when used together, will be able to be rank groundwater health within bores.

"I believe my research has contributed to the knowledge of groundwater ecosystems and undertaking my PhD has been one of my career highlights to date' says Kathyrn.

Kathryn Korbel

3D LOOK AT CRACKING SOILS

The majority of irrigated agriculture in Australia takes place on cracking soils. When deep cracks in the soil occur, irrigation water can quickly seep away beyond the reach of the crop root zone, effectively meaning that water is wasted as it can no longer be accessed by the growing crop.

Anna Greve's PhD research has gained a greater understanding of soil crack dynamics on water flow and irrigation efficiency, through the use of a new type of 3D moisture probe.

Traditional moisture probes detect only simplistic point measurements, whereas the three dimensional soil moisture measurements and monitoring of cracking depth recorded by the new 3D moisture probes will greatly improve understanding of the way water is moving through the soil. This information will give farmers crucial data for planning their irrigation schedules to ensure maximum water use efficiency.

If the 3D probes detect water is being lost into soil cracks below the root zone, reduced water application rates can be applied to allow sufficient time for the cracks to close over. Alternatively irrigation applications can be scheduled more regularly to reduce the likelihoods of cracks developing in drying soil.

"While this new technology provides a useful research tool for deep drainage researchers, practical application of this work is the next step to refine the technology to assist growers in their irrigation scheduling" says Anna.

Anna's PhD was supported by the Cotton CRC and UNSW. Anna is now a postdoctoral fellow at the Water Research Laboratory, UNSW.

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UNE Cotton Production Course

Beginning in 1994 under the CRC for Sustainable Cotton Production, The University of New England Cotton Production Course has continued through all three Cotton CRCs. The aim of this project has been to develop and deliver the only specialised university level qualification in cotton production in Australia. The course is delivered through the Diploma in Agriculture for externally enrolled undergraduates and the Graduate Certificate in Rural Science for externally enrolled post-graduates. Completion of all four units (Applied Cotton Production, Cotton Protection, Cotton and the Environment and Cotton Farming Systems) is required to achieve formal recognition by a university award.

The 'Cotton Course', as it has become known, has seen approximately 190 students successfully graduate. It has been coordinated by a UNE-based lecturer funded by the Cotton CRC and dedicated full-time to the project. Over the years successive lecturers, Steve Buster, Guy Roth, John Stanley and Brendan Griffith have had extensive research and/or practical experience in the cotton industry, and have drawn extensively on industry contacts provided through the CRC to help deliver the course. The success of the Cotton Course is due primarily to strong collaboration with industry and the broad involvement of cotton researchers, consultants and growers in providing relevant, up-to-date presentations and written material.

The program was designed to provide tertiary agricultural education for advisors and consultants, farmers, agribusiness, natural resource management staff and others within the Australian cotton industry. Many advisors receive little training in areas specific to cotton during their education, even at tertiary level. A structured production course enables participants to improve their skills more rapidly and exposes them to a broad range of information, cropping issues and industry contacts. The Crop Consultants Association (formerly Cotton Consultants Association) recognises the course in its classifications of membership.

> 'The cotton production course offers a great overview of the industry.'
>
> Cotton Course graduates

The Cotton Course has efficiently prepared cotton industry personnel to make sound decisions based on well-founded information. As a result, the graduates are now seeded throughout the industry and greater community, with a better understanding of production, environmental and post-farm gate issues. As well as contributing directly to the productivity of the industry, this provides a healthy basis for an articulate debate on the merits of cotton production across the agricultural and urban communities.

The Cotton CRC is confident that the industry will continue to work with UNE to make this valuable educational opportunity available to future generations of cotton industry personnel after the CRC closes.

'The cotton production course offers a great overview of the industry. It gives you the opportunity to meet growers and researchers and see firsthand and learn how the industry operates in all areas from planting to ginning.'

'It covers all relevant topics in the industry and gives you the opportunity to network with people in the industry, from students to specialists in various areas.'

UNE Cotton Course Students germination testing at CSD, Wee Waa

Sydney University and UNE Students at Cardale Property, Narrabri

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Roll of Honour 18 years of the Cotton Production Course

Adam Kay
Adam Kent
Alexandra Glauerdt
Alison Young
Amanda Goulden
Amanda Macalpine
Amanda Mills
Andrew Ceeney
Andrew Dougall
Andrew Price
Andrew Schipp
Andrew Ward
Angus Moore
Angus O'brien
Anna Simmons
Annabel Twine
Annabelle Douglas
Anna-Louise Ponting
Anne Johnson
Anne Sullivan
Anne Tuart
Anthony Heckendorf
Anthony Street
Arthur Procter
Arthur Spellson
Benita Inchbold
Billie-Jo Halit
Brendan Barry
Brendan Griffiths
Carolyn Johnston
Catherine Hare
Catherine Perrett
Charles Clark
Christine Grant
Christian Powell
Christopher Clarke
Christopher Collyer
Christopher Mccormack
Christopher Teague
Craig Mcdonald
Dallas King
Damien Courtier
Damien Erbacher
Daniel Gall
Daniel Hickey
David Boyle
David Brown
David Mcclure
David Ryan
David Schulze
David Taylor
David Wood
Diane Carpenter
Dianna Owens
Donald Taylor
Dugald Spenceley
Edwina Graham
Elissa West
Elizabeth Chambers
Emma Carrigan
Emma Twine
Evan Brown
Geoffrey Brown
Geoffrey Rudd
Georgina Krieg
Gerard Thom
Glen Pinn
Glenn Lendon
Graham Boulton
Graham Schultz
Gregory Kauter
Gregory Rigby
Gregory Salmond
Hamish Mcintyre
Helen Mudford
Henry Chambers
Hugo Weissen
Ian Leonard
Ian Murray
Jacquelyn White
James Bible
James Hill
James Mulligan
James O'connor
James Quinn
Jamie Street
Janelle Reichstein
Jason Lonergan
Jason Smith
Jason Thomas
Jeffrey Noonan
Jemima Maslen
Jenelle Hare
Jeremy Dawson
Jessica Cohen
Jessica Holland
Jessica Thomas
Joanna Oliver
Joanne Price
Jocelyn Sevil
Jock Coupland
Jodie Pedrana
John Rourke
John Stanton
John Stewart
John Thompson
Jonathan Bennett
Jorian Millyard
Joseph Hoffmann
Joshua Connell
Julie O'halloran
Justin Luckel
Karen Kirkby
Katrina White
Kelly Chapman
Kenneth Bullen
Kenneth Flower
Kenneth Lehane
Kim Horneman
Kim Packer
Kym Armytage
Kirrily Quade
Kirsty Hawke
Laurent Kaelin
Lee Riethmuller
Leisa Holden
Loretta Hanley
Luke Sampson
Malcolm Schmidt
Mark Baker
Mark Hickman
Mark Llewellyn
Mark Windeyer
Martin Mead
Mary Fielder
Mary O'brien
Mascha Raymond
Mathew Dent
Mathew Gaukroger
Matthew Berry
Matthew Holding
Matthew Jones
Matthew Ward
Melinda Crofts
Michael Boyce
Michael Castor
Michelle Estens
Murray Boshammer
Neil Robertson
Nerylie Gaff
Nicholas Gillingham
Nichole Mcginnity
Owen Bennett
Owen Powell
Owen Vogler
Patricia Bezzina
Patricia Hadley
Patrick Jones
Patrick Mcguinness
Patrick Sullivan
Paul Regan
Paul Weston
Pedr Harvey
Penelope Goldsmith
Penelope Van Dongen
Peta Slack-Smith
Peter Camilleri
Peter Foreman
Peter Watson
Peter-John Gileppa
Phillip Lockwood
Rachael Webb
Ramiro Martinez
Robert Annetts
Robert Boulton
Robert Ford
Robert Long
Robert Lowe
Robert Tuck
Robert Walker
Robert Ward
Rodney Mackerras
Ronald Crosby
Rory Kerlin
Rosemary Chisholm
Rowan Bennett
Ryan Pratten
Sally Melville
Samantha Millar
Samuel Powell
Sarah Jones
Sarah Kerlin
Scott Ceeney
Scott Haynes
Scott Reichelt
Sean Boland
Shane Kable
Sharon O'keeffe
Sheryl Mills
Simon Kearney
Stacey Avard
Stephen Gardiner
Steven Parker
Stewart Mason
Strath Carrigan
Stuart Doyle
Stuart Higgins
Susan Hazlewood
Suzanne Rich
Taryn Rogers
Thomas Woods
Timothy Grellman
Timothy Richards
Toby Makim
Tony Mccumstie
Troy Hunt
Viliami Heimoana
Wade Bidstrup
Wendy O'may
William Callaghan
Zeb Dawson

The Cotton CRC Summer Scholarship Program received the 2008 prestigious Business/Higher Education Round Table (BHERT) Award for Best Collaboration with a Regional Focus. The award recognises the contribution of a truly collaborative team that reaches across farmers, researchers, cotton processors, private bodies and educational providers in a rural landscape. Ms. Lisa Paul, Secretary of the Department of Education, Science and Training, presents the award to Cotton CRC Chief Scientist, Professor Peter Gregg.

Summer scholarships

The Summer Scholarship Program, which began in 2000 under the Australian Cotton CRC, provided new dimensions and opportunities for undergraduate students studying agriculture or related sciences at university. Since 2000, 65 scholarships have been awarded to motivated university students to conduct pilot projects, with 38 of them awarded by the Cotton Catchment Communities CRC. The scholarships enable undergraduate students to undertake a small research project within a current CRC research project for eight weeks during the summer.

The program has been highly successful on two counts. Firstly, it has introduced students to the cotton industry and regional Australia. Secondly, the projects undertaken by students provided an immediate benefit, enhancing or supplementing the work being undertaken within the Cotton CRC's research program.

This innovative approach to an education program helped overcome one of the major problems faced not only by the Australian cotton industry, but all rural sectors: the ability to attract future graduates as employees and postgraduate students to study in regional locations.

Summer Scholarships showing the way to higher studies

Warren Conaty received a Summer Scholarship in 2005–06 to investigate the genetic variation in relation to water logging tolerance in a wide variety of cotton genotypes.

Warren used his project as the basis of his undergraduate honours research, but, more importantly, the project exposed him to field-based agricultural research. He was able to continue his research in plant-water relations through postgraduate studies funded by the Cotton CRC. His PhD project looked at the physiological utility of using canopy temperatures to schedule irrigation in drip and furrow irrigated cotton. Warren is now working in the cotton industry, employed by CSIRO, and undertaking a postdoctoral fellowship investigating screening methods for breeding for water use efficiency.

Katie Broughton from The University of Sydney was awarded a Cotton CRC Summer Scholarship in 2007–08, working with Dr Mary Whitehouse on the behaviour of mirids in response to their predators. This work led to her receiving a Cotton CRC honours scholarship with Dr Nilantha Hulugalle to investigate root growth and turnover in *Bt* cotton.

Katie Broughton with Bruce Finney, CRDC ED.

Katie says these scholarships allowed her the opportunity to be involved in a diverse range of projects and develop an interest in both scientific research and the Australian cotton industry. She graduated with a Bachelor of Science in Agriculture from the University of Sydney, and is currently completing her PhD, examining the impacts of projected climatic changes – increasing CO_2, rising temperatures and reduced water availability – on the physiology and production of cotton in Australia.

Rising atmospheric CO_2 concentrations may have a positive effect on cotton, as increased CO_2 enhances photosynthesis and consequently growth of the plant; however, rising temperatures and reduced water availability negatively impact cotton growth and production. Katie's PhD project looks at the responses of these interactive factors on cotton. In March 2012 Katie was awarded a DAFF Science and Innovation Award for her PhD research.

International outreach and science exchange

American immigrants founded the modern Australian cotton industry in the 1960s, at a time when the USA led the world in cotton production technology. Australia now has the world's highest cotton yields and our research and researchers are internationally recognised. Many Cotton CRC researchers however, work in relatively remote locations, in the most geographically isolated developed country in the world. This meant that fostering international linkages was essential if our research was to remain world class.

Links between the USA and Australia in cotton research were already strong but the CRC further developed them and established linkages with numerous other countries, especially in Europe and Asia, through a Scientific Exchange program. International researchers came to Australia from the US Department of Agriculture, US Geological Survey, University of California, Texas A&M University, and the Swiss Institute for Plant Research. In several cases these researchers were jointly involved in the supervision of CRC postgraduate students.

Grants of up to $5,000 were awarded on the basis of competitive applications, open to all scientists, students and extension personnel in Australia for the purpose of attending, and/or presenting papers at international conferences, or to undertake short-term collaborative research.

About a third of the grants were awarded to postgraduate students, for whom international experience is particularly valuable. PhD student, Nicola Cottee, from The University of Sydney was co-supervised by researchers from Australia (Dr Daniel Tan, University of Sydney and Dr Michael Bange, CSIRO Plant Industry) and the U.S.A. (Dr Tom Cothren, Texas A&M). Her PhD project explored the use of photosynthesis, chlorophyll fluorescence, cell membrane integrity and enzyme viability to find cultivar differences in heat tolerance and see if these differences translate to yield and fibre quality.

Nicola found that being able to conduct experiments in Narrabri, Texas and Canberra meant that Australian cultivars could be evaluated for heat tolerance in comparable yet contrasting environments, from crop yield right down to the expression of one single gene under high temperature stress. She believes the Australian cotton industry can use the current agricultural climate in the USA as a model for future predictions for our industry and that American producers have a lot to learn from the Australian cotton industry in terms of long-term environmental sustainability.

About a third of the grants were awarded to postgraduate students, for whom international experience is particularly valuable.

Nicola's study found several methods that can be used to identify heat tolerance and these are being used to evaluate a range of cotton genotypes for improved performance in warm and hot growing environments.

Mitchell Burns, PhD student with Sydney University visited the University of Guelph in Canada and DuPont & Waterborne Environmental Inc. in the USA. The exchange enabled him to work under the supervision of toxicologists, Professors Keith Solomon and Mark Hanson, who are world leaders in the ecological risk assessment of agrochemicals. While at the University of Guelph, Mitch undertook a toxicity experiment to investigate the potential recovery of two species of Duckweed (*Lemna gibba* and *L.* minor) following exposure to the herbicide Diuron®. When the macrophytes were exposed to a range of concentrations, Diuron was found to reduce the population growth rate (widely considered a significant toxicology endpoint for aquatic macrophytes and algae), which is not new; however, following exposure, the macrophytes were found to recover to a point that is not significantly different to the population growth rate of the control cultures. These results highlighted questions about whether standard toxicity data adequately represent exposure scenarios that are commonly observed in catchments.

Mitchell gained experience at DuPont and Waterborne in the development and running of a spatial exposure model developed by these organisations and participated in the simulation modelling and data gathering processes under the supervision of Dr Aldos Barefoot and Dr Gerco Hoogeweg. He was able to use the same models to predict spatial environmental fate and exposure in the Gwydir River catchment.

Currently Mitchell is a research postdoctoral fellow with CIRAD in France. *"My research involves evaluating the ecological impact of pesticides within the life-cycle assessment (LCA) framework, I will be using LCA environmental fate models to predict pesticide exposure in terrestrial and aquatic environments"* says Mitchell.

"The outputs of my post doc will be used to further evaluate potential ecological impacts, such a comparison will serve to distinguish the long-term ecological sustainability of different farming environments".

"This project arose through my continued interest in tools that can be used to support management decisions for sustainable agricultural development, with a special focus on the chemical interaction of pesticides with the environment" concluded Mitchell.

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Dr Stuart Gordon of CSIRO Materials and Science Engineering (CMSE) received CRC Scientific Exchange grants in 2008 and 2012. Stuart said the exchanges were central to the development of the commercial Cottonscope instrument, which represents the combination of two CMSE technologies; Cottonscan for measuring fibre fineness and Siromat for measuring fibre maturity and maturity distribution.

Stuart's scientific exchanges provided a platform for sharing the potential of this new technology with researchers in the USA and Europe. In particular, sharing with long-time colleagues from leading research groups at the USDA ARS in New Orleans and Texas Tech University in Lubbock facilitated the development and uptake of Cottonscope. Both USA research groups have since purchased Cottonscope instruments and are considering ordering further instruments in order to increase the number of samples they can measure.

As a result of these collaborations, a number of peer review papers on Cottonscope have been, and are currently being, written by researchers from these laboratories. These papers will be influential in the uptake of Cottonscope by the wider cotton industry.

A scientific exchange grant enabled Dr James Mahan of the US Department of Agriculture, Lubbock, Texas, to visit the Australian Cotton Research Institute at Narrabri. Dr Mahan's visit was to ensure that the BIOTIC (Biologically Identified Optimal Temperature Interactive Console) irrigation scheduling tool was assembled in the correct fashion in field trials for University of Sydney PhD student Warren Conaty (see page 183). As a result, an invaluable relationship has been established between Dr Mahan and cotton researchers both in Narrabri and The University of Sydney. The formation of this relationship resulted in Dr Mahan becoming one of Warren's PhD supervisors, which contributed importantly to his research.

Table 2

	Completed	Current	Withdrawn	Total
PHD STUDENTS	40	20	3	60
HONOURS STUDENTS	15	0		15
MASTERS	2	0		2
SUMMER SCHOLARSHIPS	38	0		38
SCIENTIFIC EXCHANGE	61	0		61


COTTON INCORPORATED
Alfalfa Mowing / Lygus Movement Study


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Science in Schools

– Looking towards the future

The future of Australian science and agriculture is dependent on young people undertaking studies in this field. The Cotton CRC schools program aimed to promote the study of science and agriculture in both primary and secondary schools.

Central to the success of Science in Schools was the Cotton CRC's Education Officer, Trudy Staines, who facilitated, implemented and managed the delivery of all schools-based activities.

In 2009, the Cotton CRC joined forces with the Primary Industry Centre for Science Education (PICSE) and the Cotton Research and Development Corporation (CRDC) to further promote science careers, science-based industries and research to high school students and teachers. PISCE and the Cotton CRC bought together schools, higher education institutions, businesses and science-based primary industries to undertake the shared task of addressing declining student participation rates in tertiary science programs and the associated shortfall in skilled industry personnel.

In her shared role of Science Education Officer with PICSE and Cotton CRC Education Officer, Trudy Staines organised student placements within the cotton industry, produced cotton-specific teaching resources and was the central contact point for schools. She found that the partnership with PISCE meant the Cotton CRC was able to reach further across the education system and assist in creating a more positive view of the vast range of excellent careers available in agriculture, with particular reference to the cotton industry.

Making science fun with Dr Karl and
Trudy Staines Cotton CRC Education Officer.

SCIENCE IN SCHOOLS STOCKTAKE

- 2 Science Investigation Awards – 47 entries, 781 students
- 2 Cotton Industry Student placements
- National Science week activities
- Amazing world of science
- School modified Field to Fabric Course delivered to 92 high school students
- Australian Museum's 'Science in the Bush' delivered to 1000 north west NSW school students
- 865 Enviro-Stories entries received from over 1200 participating school students, with 52 winning entries published.

The Enviro-Stories competition
- 'Kids teaching Kids'

The Enviro-Stories competition was central to the overwhelming success of the Cotton CRC Schools program, encouraging students in grades three to seven, across nine catchment areas, to explore their local surroundings and write a 16-page school reader.

The competition was designed so the participating schools were able to meet syllabus requirements in english, science, studies of society and environment, and creative arts. It is based on the pedagogy of 'Kids Teaching Kids', providing an important learning process as older students write and illustrate the simple books for younger children to read as part of their literacy education.

A comprehensive education kit, which explored the year's theme and included teachers' notes, fact sheets and activities for students, was created to assist teachers with the delivery of the competition.

To date, a total of 865 entries have been received from over 1200 participating school students, with 52 winning entries published. The winning readers are distributed annually to over 400 schools, community groups and local libraries throughout the cotton growing regions, from the Fitzroy basin in north Queensland to the Murrumbidgee in southern NSW.

Competition themes have included:

- Bugs, beetles, birds and bats
- Creepy Crawlies... Life underground
- Fur and Fins, Feet and Beaks:
  What can you find at your local creek?
- An Aussie Bush Tale.

The Enviro-Stories competition was established in collaboration with PeekDesigns and the Central West CMA, who will continue to run this highly successful program post the Cotton CRC.

The enviro-stories competition is a fun literacy program which aims to promote science environmental education in primary schools. Winning entries are published and distributed throughout the nine cotton growing catchments.

RIVER RALLY ...FUN BY THE WATER: The CRC's Education Program supported the River Rallies conducted by Namoi Catchment Management Authority, NSW DPI and Waterwatch. River Rallies are a unique environmental education initiative which allows children to experience firsthand learning experiences of the riparian environment.

The vocational pathway

Historically the Cotton industry's education and skilling programs were never aligned to the national vocational education and training (VET) framework. However, during the Australian Cotton CRC, the industry started exploring the benefits of such an alignment and this was further developed in the current Cotton CRC with the appointment of a Professional Development Manager (Mark Hickman, DAFF Queensland). In this role Mark has established and coordinated several significant vocational partnerships and programs for the industry.

Cotton Basics

Cotton Basics is an example of how the industry engaged with the secondary school program via the vocational pathway. The delivery of cotton related vocational studies were limited within the secondary schools system, as it relied on the teacher delivering competency units within a general certificate II in Agriculture using cotton examples and was highly dependent on teacher experience and resources. For schools that wished to deliver cotton specialised qualifications for Certificate II and Certificate III, it was apparent that the content, the equipment and the skills being delivered did not reflect industry practice. Mark Hickman Professional Development Manager said a guiding principle is that all training should reflect current industry practice, meaning that the Certificate II Agriculture (cotton specialisation) qualification needed to be remodeled. Hence, Cotton Basics was developed and endorsed by the vocational sector.

However, Cotton Basics is more than documentation, it is a delivery and engagement strategy for industry. There are two key strategies for the delivery of Cotton Basics. The first is the provision of professional development training for teachers by industry researchers and extension staff. This provides the teachers with the fundamentals of the industry, an understanding of industry terminology, the latest research and assures they have class creditability when teaching students from cotton backgrounds. Secondly, delivery of this style of vocational training requires full school leadership engagement as there can be timetabling issues associated with a block release and teacher PD program. Cotton Basics is a unique program, as students who complete the qualification are workforce ready for cotton and possess current skills and industry knowledge. Numerous employment outcomes have been achieved by the 33 graduates over 2 years period in which it was delivered.

> “The Cotton and Grains Irrigation workshops help consultants like me make better decisions which, inturn, benefits the productivity of growers. Benchmarking is a difficult concept to get across but it leads to better practice. This work also shows the broader community we are actively improving all the time.”
>
> Russell Ison,
> Agribusiness Consultant Carroll NSW

Aligning extension and education with VET practices

An innovative strategy instigated by Mark Hickman in the CRC was to merge traditional cotton industry extension programs with vocational methodology to deliver a modern extension program targeting multiple industry outcomes. The Cotton and Grains (C&G) Irrigation Workshop series, provided a practical example of this beneficial linkage. The C&G workshops were a series of three hour in-field events delivered as traditional field days. The workshop series were developed to assist the adoption of industry research in water management by building water management skills within an embedded vocational assessment. The vocational alignment provided greater structure to the extension workshops as well as a clear pathway for producers to obtain a formal qualification in the future if they wish to do so. Ultimately this approach capitalised more efficiently on the time the participant invested.

Pumps workshop, part of the Cotton and grains irrigation series,Walgett NSW.

The relationship between VET and *my*BMP

The cotton industry implemented the very successful and well supported best management program *my*BMP which promotes industry research and establishes benchmarks for sustainable business management. Through a collaborative relationship between Tocal College (NSW) and the Cotton CRC, a new *my*BMP industry award was created based on the skill sets practiced in the workplace. The award captures the linkage between the implementation of industry best management program and the educational standards outlined in the National Training packages within the VET sector.

The Certified *my*BMP Farm Manager Award, recognises prior learning and skills under the Vocational Training and Education system. It enables cotton growers, managers and farm workers who have been instrumental in implementing *my*BMP to have this effort formally recognised with an industry award. This award is equivalent to a Diploma of Agriculture specialising in cotton production. The Certified *my*BMP Farm Manager qualification presents a marketable asset, acknowledged and endorsed by the cotton industry. The qualification will be recognised by future employers, within and outside the cotton industry, as having achieved best practices accreditation for a managed property. Since its establishment there have been 41 people awarded with this qualification.


WINTER
VISITOR

Building Industry Human Capacity through Workshops

The three Cotton CRCs have ensured that the Australian cotton industry is a world leader in cutting edge research and development. But this R&D effort is wasted unless individuals across the industry and its related sectors are actually inspired and informed enough to adopt it in the day-to-day running of their enterprises. Thus, implementation has been core to the work of the Cotton Catchment Communities CRC.

We have achieved this by devising and conducting client-focused short courses and workshops (both accredited and non-accredited) to promote industry research and best practices to the people who can use it the most and make a significant difference to the industry. When the new Cotton CRC began, the target was to deliver this training to at least 200 industry personnel. This milestone has been well and truly exceeded, with 68 short courses delivered to 1008 people by the start of 2012. These short courses and workshops range across the CRC's programs and thus have built human and business capacity associated with farming, the environment and the community.

Mark Hickamn Professional Development Manger said to build and enhance human capacity it requires the development of the Skills , Communities and Systems that assist the individuals to build their own capacity.

'When this capacity is then applied to the workplace it is able to enhances the industry's ability to innovate, in addition to personally growing the individual'.

The following are a snap shot of the courses developed and/or delivered by the Cotton CRC community.

> "Apart from being a grower there are many people along the line that contribute to fibre quality. [The course] allows you to see and understand that line and the factors and processes that affect the raw product to the finished product."
>
> Cotton grower participant

Cotton Field to Fabric Course

This highly successful course sought to increase participants' understanding of how their actions and management in their roles within the cotton supply chain impact the quality of the final product. To create this knowledge and establish the required practice change within the supply chain, the course focused on the various trigger points that can cause fibre damage or influence fibre development.

The Field to Fabric course firstly examined the important agronomic and management practices performed in the field. Secondly, it focused on the role of mechanical harvesting and ginning in maintaining fibre quality and thirdly, it investigated points of differentiation when converting lint into yarn for consumption by the textile industry.

René van der Slujis (CSIRO) coordinated this three-day course, held at the CSIRO research facilities in Geelong, Victoria, either once or twice a year, subject to demand. Eleven courses have been conducted between 2006 and 2011, with 264 participants. The location allowed participants to interact with CSIRO's commercial scale fully operational spinning, weaving and dying machinery. Participants ranged right across the value chain – cotton producers, cotton extension officers, ginning personal, cotton merchants, overseas spinning mill personnel and even textile students from the Melbourne universities.

Our capacity building program took the “Cotton Field to Fabric” course beyond the industry.

In 2009 the extremely popular “Field to Fabric” course was revised to assist local New England/North West high school students and teachers to better understand Australia’s favourite fabric. The course was redesigned and made more suitable for agriculture, biology and design and textiles students. The course now incorporates more simplified modules on cotton growing, ginning, classing, to fabric formation and dyeing providing insight from the farm gate to the finished product. It has been an effective way to deliver cotton production information to schools and provides excellent information for HSC test examples. A total of 92 students have completed this course.

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Centre Pivot and Lateral Move System Evaluation Short Course

With increased purchase of new, and recommissioning of existing, Centre Pivot and Lateral Move machines, it became apparent that there was a need to skill producers and the agribusiness sector in optimising the equipment's performance.

Following a review of the irrigation sector literature and discussions with various irrigation specialists the Cotton CRC decided that a project team should be established and a course developed with a twofold purpose: first, to encourage more commercially available experts with the necessary skill sets to perform the assessments and; second, to highlight to growers the value of having the assessment performed by outlining the efficiencies that could be gained.

A system evaluation course addressed the fundamental aspects of the machines for efficiency gains. The course demonstrated the value and science required to perform an irrigation audit of an overhead system. In one case, an 18 per cent irrigation efficiency was achieved with modifications implemented after the training.

As a first for the cotton industry, this workshop evaluated the potential of delivering the course using a blended (online plus face-to-face) learning platform to cater for various learning styles. This approach was made possible by engaging the Australian Agricultural College Corporation (AACC) in Queensland to develop an online learning and assessment resource for the workshop, with resources aligned to a vocational irrigation competency unit. There have been three courses with 25 participants, who represented a total of 50 Centre Pivot and Lateral Move machines or 2376 irrigated hectares.

Utilising Biodiversity on Cotton Farms

DAFF Queensland and Cotton CRC Cotton Extension Officer, Ingrid Rencken, developed an industry workshop that assisted farmers to identify biodiversity on their farm and, subsequently, to utilise these assets in daily management decisions. Workshop discussions included the role of riparian zones and the use of natural vegetation as an insect predator habitat, such as a bat roost, in order to aid in-crop control or as wildlife corridors. The workshops focused on creating awareness of the biodiversity issues within the cotton landscape, as well as promoting the natural resource module in *my*BMP. Workshops conducted on the Darling Downs, supported by a series of information fact sheets for the broader industry promoting biodiversity linked to sustainable cotton production, were well received by the industry.

The Cotton CRC has placed great priority on its most important resource – its people. Through the establishment of an ambitious Education program we have sought not only to enhance the skills of existing research and extension staff, but to attract and train a new generation of high calibre researchers for cotton and other agricultural and environmental sectors. We have also helped inform, educate and enthuse the general public about agriculture, at all levels from primary and secondary schools, through undergraduate and postgraduate university levels, via comprehensive and innovative outreach and work experience programs. This combined with a rigorous Training program aimed at enhancing the skills of growers, consultants and cotton industry personnel means that the Cotton CRC is able to retire from the industry confident that the benefits of CRC Education and Training programs will reverberate throughout the industry and the wider community for many years to come.

Yvette Cunningham

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The practical interpretation and adaptation of cotton research outcomes has played a critical role in the sustained improvement and increased production of cotton in Australian over the past 30 years. It has been a pleasure for the Cotton Catchment Communities CRC to operate within a well-educated industry with participants who are keen to learn and adopt our R&D outcomes. In response to this industry culture, we have sought to deliver innovative education and extension systems that provide the skills, knowledge and capacity needed to achieve this result.

As with most cooperative research centres, our research was not merely theoretical: our aim was to ensure it translated into real and measurable benefits to the productivity, sustainable and profitability of the Australia cotton industry, its catchment and its communities.

An important part of the work of the Cotton CRC, one of immense significance in improving the industry's environmental performance, has been the technical support our researchers have provided to enhance the development and adoption of the cotton industry's Best Management Practices (*my*BMP) system (www.mybmp.com.au).

The Cotton CRC has supported a diverse range of innovative extension, education and training activities and, at the end of our term, we can say with some confidence that the Adoption Program has proved to be a successful mechanism for ensuring our R&D outcomes have translated to real on-ground change, not only by growers but also by industry bodies, government agencies and the community.

'The Australian cotton industry, to an extent probably unparalleled in Australian agriculture, is committed to continuous improvement.'

Yvette Cunningham

Program Leaders

Yvette Cunningham 2009 – 2012
Letitia Cross 2006 – 2009

Managing uptake of new knowledge and knowledge exchange

As with many CRCs, the Cotton CRC faced a number of research adoption challenges including delivering science to achieve the best possible outcomes.

Adoption across multiple sectors

The research portfolios of the previous two Cotton CRCs had focused primarily on production end-users; however, as its name, the Cotton Catchment Communities CRC implies, the remit widened greatly for the third CRC. The new Catchment and Community Programs introduced research knowledge and tools relevant not only to the agricultural sector, but also to the environmental, economic, government and community sectors, often in combination, rather than a single, well-defined stakeholder group.

Adoption for the public good

As with many agricultural and environmental organisations, the pathways to adoption are not always through third party commercial products but, rather, by informing policy and practice for social, environmental and economic benefit. Public domain outcomes and outcomes that benefit a large number of small to medium enterprises, such as cotton farms, are delivered more effectively through adoption channels such as communication, extension and education.

Responding to these needs, the Cotton CRC developed a number of new adoption pathways that contributed to information transfer, practice change and research uptake. Knowledge emerging from science and practice management was developed into integrated suites of products, tailored to meet the needs of the respective audiences. End-users were an integral part of this product development through trials, working groups and steering committees, which ensured greater grower/end-user ownership and thus increased adoption levels and more targeted scientific outcomes for the industry.

The D&D team at the Southern NSW Cotton expo, Griffith showcasing best practice in cotton production.

Making a difference through extension

The members of the Development and Delivery Team (D&D) (formerly the National Cotton Extension Network) have been pivotal in giving the Australian cotton industry a distinct international advantage through early adoption and uptake of research outcomes. The D&D team is made up of Cotton Extension Officers who operate throughout cotton growing areas, providing the necessary conduit between researchers and end-users to facilitate change at the farm level.

The structure and organisation of the Cotton CRC National Cotton Extension Network was developed during the term of the Australian Cotton CRC; however, as the new CRC began to implement its wider remit, the team evolved and new roles emerged, with the team providing significant support in extending environmental outcomes.

The extension network allowed for collaboration across state boundaries and acted as a linchpin for many researchers functioning in different states. Yet as the drought hit, team numbers declined rapidly and a new approach was required to disseminate information.

In 2009, the Cotton CRC, CRDC and Cotton Australia worked collaboratively to restructure and refocus the extension and knowledge system services. This resulted in the establishment of the Development and Delivery Team (D&D). The new team moved away from regionally based extension to a more target-based approach which operated at the national level. This new commercially oriented system also focused on using a campaign-style for development and delivery to the industry.

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D&D target leads delivered extension campaigns based around the following core areas;

- **Biosecurity (disease and weed management)**
  Susan Maas, Emerald, QLD
- **Crop nutrition and soil health**
  Duncan Weir, Toowoomba, QLD
- **Integrated pest management**
  Sally Ceeney, Warren, NSW
- **Innovative farming systems**
  Dallas King, St George, QLD
- **New growers and weeds**
  James Hill, Hay, NSW
- **NRM**
  Stacey Vogal & Peter Verwey, Narrabri, NSW
- ***my*BMP**
  Jim Wark & Rebbecca Rogan, Toowoomba, QLD
- **Social research**
  Kate Schwager, Narrabri, NSW

Additional to the provision of subject matter expertise surrounding the adoption targets, a further core role of D&D was to advise the industry on emerging issues and lead the response as a cohesive team.

The overarching objectives that guide how the D&D team operate include:

1. Engaging with researchers, extension officers, service providers, consultants and growers to develop a cohesive working group that identifies and responds to areas of need within the target area,
2. facilitating a coordinated extension program across the industry, and
3. providing regional support and maintain the industry presence.

Ken Flower, Research Implementation Manager, said the new approach utilised innovative delivery methods through varying combinations of agribusinesses, contracted delivery specialists, existing regional extension staff and the recently relaunched best management practices system, *my*BMP.

"Through the D&D team's passion, dedication and sound research knowledge they have successfully continued to extend up-to-date and relevant information across all cotton growing regions, despite the structure shift and changes".

An excellent illustration of the D&D responsiveness was the role which team members played in mitigating the impact of floods and major rains in Queensland in the middle of the 2010–11 cotton season. Team members assisted growers and consultants to make crucially important decisions on how to manage flood-affected crops, utilising broad R&D knowledge gained on optimised cotton production in tropical regions.


Susan Maas


Duncan Weir


Sally Ceeney


Dallas King


Jim Wark


James Hill


Stacey Vogel


Peter Verwey


Rebbecca Rogan


Ken Flower

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"*Given the wide range of research and development work that the cotton industry undertakes, it is important to be able to measure impact across all disciplines quickly and regularly. The target-based approach proved to be of great assistance in the accurate and timely monitoring, evaluation and management of industry progress*", says Ken.

Moving away from a generalist, regionally based extension approach to a target-based campaign approach also enabled the team to be more flexible and address industry needs more rapidly. This proved to be especially useful when dealing with outbreaks of new pests and significant damaging flood events.

The Cotton CRC has delivered specialist information tailored to the needs of the growers in a rapidly expanding industry. Extension activities cover a range of multi-faceted information channels including training workshops, field days, factsheets, area wide meetings and production manuals.

Research projects are not complete without an extension component, hence examples of these campaigns and extension efforts are referred to throughout this document with a snap shot of the teams efforts outlined below.

Biosecurity: always on the lookout

Farm hygiene underpins successful biosecurity management. A number of major pests and diseases harbour in volunteer cotton and ratoon cotton. Other weed hosts allow pests such as silverleaf whitefly, cotton stainers, aphids and now mealybugs to maintain populations over winter. Higher starting numbers give pests the edge over their natural enemies and reduce the number of generations it takes to reach outbreak levels. In addition, volunteers and ratoons allow inoculums of soil borne diseases such as black root rot, fusarium wilt and verticillium wilt to build up, while host vectors of diseases such as cotton bunchy top and tobacco streak virus are frequently sustained in volunteers, ratoons and naturally-occurring host plants.

Disease and farm hygiene are persistent problems where the practice change required is pre-emptive and the benefits, while obviously impacting commercially in the future, are not necessarily apparent up front. Adoption of good farm hygiene and disease management practices therefore require long term attitudinal changes by growers.

The management of volunteer and ratoon cotton was identified as a significant challenge for the industry and a campaign lead by D&D Team member, Susan Maas of DAFF Queensland aimed to raise farm hygiene awareness and address the barriers to adoption which existed.

The extension focused primarily on:

- Ensuring growers and agronomists were aware of these issues
- Acting to remove these barriers through the delivery of appropriate training and identifying areas of future research


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industry
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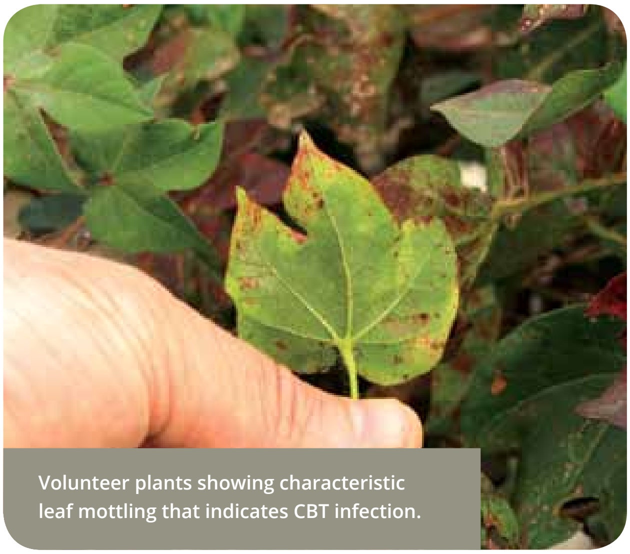

Volunteer plants showing characteristic leaf mottling that indicates CBT infection.

'*Break the Green Bridge' and 'War on Weeds' were some of the first campaigns developed, using the emerging issue of Cotton Bunchy Top as the motivator to encourage growers to put farm hygiene, in particular control of volunteer and ratoon cotton, as a top priority*' said Susan Maas.

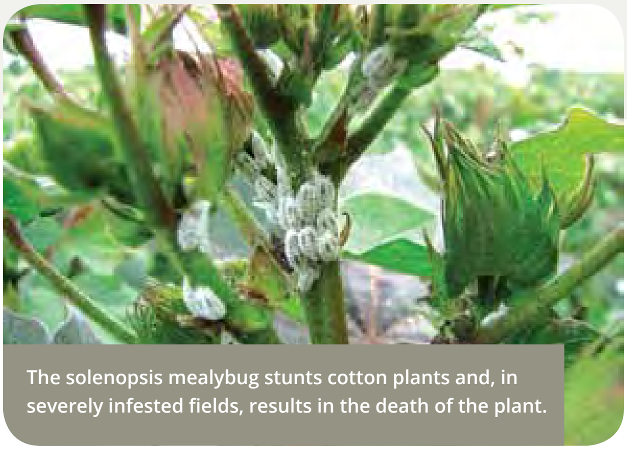
Cotton Bunchy Top (CBT) is a viral disease spread by cotton aphid *(Aphis gossypii)*, which became widespread in the 2010-11 season. Fields in NSW and Queensland were seen as having more than 70 percent of plants infected. This disease had a devastating impact on yield and the D&D Team developed a 'Breaking the Green Bridge' campaign to control over-wintering CBT hosts by removing all cotton volunteers and weeds.

The campaign included raising regional awareness through meetings, a widespread media campaign and extension material. Crop Consultants Australia (CCA) were involved in designing and implementing a survey and action plan process to significantly reduce cotton losses to CBT in the 2012 season. The CCA was contracted to survey growers to determine their risk of CBT, producing benefits which were twofold. All consultant members of CCA were trained in how to identify, manage and reduce the risks of this disease. This ensured strong support for the campaign messages from this influential sector. Growers were encouraged to discuss implications of their CBT risk profile with their agronomist consultant, a highly trusted source and the key person able to provide farm-specific advice. The outcome from this collaborative CCA and Cotton CRC approach was to have over 90% of growers surveyed and develop an action plan. Then incidence of CBT in the 2012 season was far lower than in 2011.

Quick response to exotic pest outbreak

An increasing number of growers from west of Emerald in central Queensland reported the presence of mealybug in cotton crops early in the 2009–10 season and it became clear this was becoming a serious problem. The Cotton CRC, CRDC and Cotton Australia, along with DAFF Queensland and Biosecurity Queensland, quickly formed an Industry working group and initiated a range of actions to protect the cotton industry. Cotton CRC researchers and extension personnel played a major role in identifying the mealybug as an exotic (imported) pest. This species, *Phenacoccus solenopsis,* had been identified in Texas in 1990 and Pakistan and India in 2004 and has caused significant economic loss within those cotton industries.

The solenopsis mealybug stunts cotton plants and, in severely infested fields, results in the death of the plant. Many questions emerged about its potential impact on cotton in Central Queensland and beyond in future seasons, especially as there was no significant research available, nor had control mechanisms been developed. In response, Dr Melina



The solenopsis mealybug stunts cotton plants and, in severely infested fields, results in the death of the plant.

Miles and Dr Paul Grundy of DAFF Queensland were pivotal in developing research to understand the mealybug ecology, especially its over-winter survival strategies, and in evaluating control options.

The Cotton CRC funded a survey in the Emerald region to firstly determine the extent of the infestation and the amount of damage it was doing to the cotton crop. The survey also investigated any factors that could be associated with the presence or absence of infestations which might provide indicators as to how to manage this threat in the future. The resulting extension effort, led by D&D Team Specialist, Susan Maas (DAFF Queensland), focused on the adoption of rigorous farm hygiene practices and the preservation of beneficial insects such as lacewing insects and the Cryptolaemus ladybeetle as part of an Integrated Pest Management (IPM) approach.

As a result of this extension effort, the Central Highland Cotton Growers and Irrigators Association (Research and Technical Committee) collaborated with the cotton industry working group to develop the 'Come Clean Go Clean' Protocol. This has been critical in enabling picking contractors to enter and leave the area without spreading the exotic mealybugs to other areas.

"Bisoecurity extension is a juggling act, yet we are seeing a cultural shift which is evidence that our campaigns are hitting home, growers are prioritising farm biosecurity and the control of pest hosts such as volunteers and ratoons" says Susan.

WINNER OF THE 2010 CHRIS LEHMANN YOUNG ACHIEVER OF THE YEAR

Susan Maas has been a key contributor to the cotton industry in the Central Highlands and Dawson Valley regions. As a result of her extraordinary knowledge and understanding of cotton production agronomy and technology, Susan enjoys a great partnership with the regional grower associations at Emerald and Theodore and with the cotton crop consultants.

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A successful 'wanted' campaign was developed by the Development and Delivery Team. This campaign highlighted the importance of managing weeds, cotton volunteers and ratoons on farm to growers in order to keep disease such as cotton bunchy top and exotic pest as mealybugs from spreading.

Crop nutrition

Crop nutrition and soil management are as important in optimising returns and managing long term sustainability as pest, disease or water management. Nitrogen is an essential, but expensive input to cotton farming systems. Optimising nitrogen inputs to meet plant needs is known to minimise losses of applied nitrogen to the atmosphere and is also beneficial in terms of increased nitrogen use efficiency and profitability.

A considerable amount of research in cotton nutrition and soil health has been conducted, from which it clearly shows that growers were over applying nitrogen and significant losses were being incurred.

The Cotton CRC through DAFF Queensland, coordinated a campaign which aimed to have 50 percent of hectares compliant with industry best practice as defined by BMP guidelines for soil health and crop nutrient practices and 70% of hectares utilising objective measurements to adjust nitrogen applications. In addition, the project "Accelerating adoption of integrated soil management practices in irrigated cotton and grain", was established to assist rejuvenated soils extension and emphasise the importance of soil health in the irrigated cotton and grains industry.

Duncan Weir, target lead for Soil Health and Crop Nutrition, said these findings implied there had been a market failure that required a focused campaign to address this issue.

"*Growers would not apply an insecticide to a crop before it has been checked and the same reasoning should apply to fertilising a crop*", Duncan says.

"*It was recognised that a more coordinated approach to the delivery of research outcomes and the adoption of industry best practice for Soil Health and Crop Nutrition was required*".

“*To address this issue the industry focus group was established. It pooled expertise among crop nutrient researchers, extension officers, industry representatives, service providers and growers from across the cotton industry*”.

The group aimed to review research, identify research gaps, revise current best practice standards within the *my*BMP program and develop extension activities to meet industry demands.

This integrated soil management project used market research to determine the soil extension needs for irrigated cotton areas in NSW and Queensland. Existing information was collated and reshaped into an extension program consisting of training workshops, field days, regional soil forums, published case studies and on farm demonstration sites. Eleven case studies were published. Three regional healthy soil forums were held in Goondiwindi, Narrabri and Hillston. Sixteen training workshops on soil nutrition, soil pits, understanding soil testing and property planning were delivered to agribusiness, consultants and farmers, with a total of 167 attendees.

Another successful campaign targeting Nitrogen use efficiency was rolled out by the Development and Delivery Team.

“*Growers should know the nutritional status of their soils before they apply fertilisers as this represents a major production cost and getting it right can significantly improve returns. Soil and leaf testing and analysis provide growers with quantitative information from which informed decisions can be made on crop nutrition, fertiliser programs and other cultural practices*”, Duncan says.

The campaign exceeded its targets. It reported that 85 percent of CCA-surveyed growers are developing and implementing soil health/crop nutrition management plans. Growers are incorporating crop rotations, minimum/conservation tillage, GPS guidance systems, permanent beds and yield mapping in their management plans. In addition, a further 85 percent of growers and 100 percent of consultants are utilising soil test to calculate crop nutrient requirement.

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Cotton – A mover and shaker

In 2009, cotton emerged as the new “hot” crop of choice for farmers in the Murrumbidgee and Lachlan Valleys of NSW.

While traditionally not grown commercially in the region for many decades, cotton plantings in Griffith, Darlington Point, Hay and Coleambally increased from 1,500ha to over 30,000ha in a few short years. Interest began to grow as water availability became more reliable. For many, new opportunities surrounding a crop like cotton that could be sold on the futures market three years in advance made it an attractive option. At the same time, significant expansion occurred across all production regions in the 2010-2011 and 2011-2012 seasons, and many new growers joined the ranks of their experienced counterparts growing much expanded areas of both irrigated and rain-fed crops.

It became apparent that the industry lacked reliable R&D information packages expressly suited to inexperienced growers. In response, the D&D Team produced the first comprehensive Australian Cotton Production Manual mid-2011. This manual has since become a key product that aims to summarise the key decision points at all stages of the cotton production cycle. D&D Team members and leading industry researchers are direct contributors and editors of this important information product. Extensive support from advertisers and sponsors underwrites the annual cost of production and distribution of the Australian Cotton Production Manual, and the support of Greenmount Press is also vital to undertake production and advertising sales.

New grower specialist, James Hill, is based in the industry’s hot-spot for new growers, Southern NSW. He says the key to a successful industry in the south is earliness. This is due to the shorter season, thus growers need to plant as soon as the temperatures allow. Knowledge of this key factor underpins much of James’ regional extension role where he works across the services sector to extend industry best practice advice. Numerous hands-on and practical field walks, planter set-up meetings, Integrated Pest Management, season-end planning and harvest have been the hallmark of James Hill’s Cotton CRC extension efforts.

Cotton plantings in Southern NSW, Griffith, Darlington Point, Hay and Coleambally have increased from 1,500ha to over 30,000ha in a few short years.

‘These growers are progressive people who are keen to take on new challenges and learn new skills to extend the diversity of their farms’.

‘We have had to go back to basics, as many growers are returning or entering the industry for the first time. Their thirst for information and best practice uptake makes it essential that they have access to the latest information tailored to the unique conditions of growing in the south’ says James.

Providing easy-to-understand information and tools are essential for the future success of cotton in the Lachlan and Murrumbidgee valleys. Through the new grower campaign, the CRC has been able to deliver specialist information tailored to the needs of the growers.

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One of the reasons the cotton industry has been so successful is due to its openness in sharing ideas and the exchange of information that occurs between growers, both new and old across regions. It has never been the CRC's intention just to complete research and file it for future use. The task is not complete until adoption or adaptation occurs. We have aimed to concentrate on research that is relevant to both the short and long term future of the industry, and then to devote equal resources to transmitting the results of this research.

The evolution of the D&D team over the past seven years means as the team enters a new era it is in a strong position to deliver best practice extension services to an industry that is eager to embrace research driven farming and environmental practices.

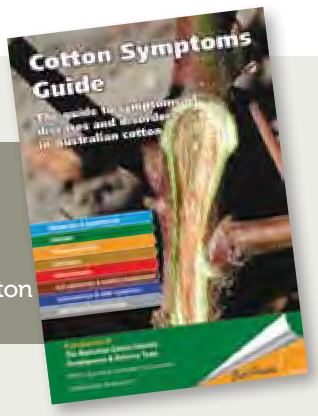
Australian Cotton Production Manual

This manual serves to give growers, new and old alike, key information, based on best science to help successfully and sustainably grow high yielding and high quality cotton, and provide advice on where to obtain more detailed information and tools when necessary.

Cotton Pest Management Guide

This guide is used by growers, consultants and agronomists throughout the cotton season as the main point of reference for insecticide and herbicide uses, resistance management, Integrated Pest Management (IPM) information and management plans for GM technologies.

Cotton Symptoms Guide The guide to symptoms of diseases and disorders in Australian cotton



This publication provides a guide to the symptoms of the diseases and disorders that may be observed in Australian cotton crops. It also provides descriptions of those diseases identified as 'priority pests' or 'biosecurity threats' in our Farm Biosecurity Manual for the cotton industry. These are diseases we don't have and don't want in Australia! Quarantine is vital!

Pest and Beneficials in Cotton Landscapes 2011

This publication provides a practical ute seat guide to correctly identifying and understanding the key operations and interaction of these insects in both the cotton area and the natural landscape areas on cotton farms. This breakthrough product is the first guide designed for in field decisions in relation to pests and beneficials which has detailed ecosystem services benefits and analysis listed.

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New technologies increasing adoption

Best practice: *my*BMP for growers – powered by research

The Australian Cotton Industry's Best Management Practices (BMP) Program was established in 1997, with the initial purpose of improving the industry's management of pesticides. It was developed as a voluntary farm management system providing self-assessment mechanisms, practical tools and an auditing process to guarantee that cotton is produced using best practice. The program was based on a process of continuous improvement using a 'plan–do–check–review' management cycle.

BMP's goals were to see the development of a cotton industry:

1. whose participants are committed to improving farm management practices;
2. whose participants have developed and followed policies and farm management plans that minimise the risk of any adverse impacts on the environment or human health; and
3. which can credibly demonstrate stewardship in the management of natural resources and farming operations?

Independent auditing and certification processes led to the formal recognition of farms for their BMP attainments. BMP became a system for documenting the uptake of scientifically proven farming practices – an industry-supported initiative that placed the combined research, development and extension efforts of successive Cotton CRCs at the heart of the program.

BMP was a proactive initiative that enhanced cotton growers' social licence to farm. It gave the cotton industry the opportunity to demonstrate to the community, governments and cotton markets its ability to use and mange various technologies, such as pesticides and gene technology, efficiently and responsibly. It also provided a systematic process for the cotton industry and its growers to contribute to the catchment planning and natural resource management goals of government.

Despite these undoubted gains, the BMP program had faced a number of challenges since its introduction. Some growers found it difficult and intrusive, not relevant to current issues and providing no direct financial gain to the individual. As a result the program lost momentum and a new strategic direction was needed to make the program more relevant to holistic farming businesses. Consequently, a revised structure, which included water, soil, chemicals and IPM, carbon and energy, biosecurity, technologies, natural assets and human resources, was embarked upon in 2008.

The introduction of *my*BMP

2010 saw the launch of the new *my*BMP, a web-based management system based on the original BMP manual but replaced with a user friendly, constantly updated, web-based tool. It represents a complete reinvigoration of the content and scope of BMP as well as its method of implementation and delivery.

*my*BMP provides a centralised location for growers and industry personnel to access the latest information and research, find solutions to challenges that may arise and provide a wide variety of tools and features to help industry members operate at optimal efficiency. Most importantly, as a web-based system, it is flexible and easy to use, able to record and distribute information instantly, provide updates and make immediate changes as they are required.

*my*BMP has been designed to accommodate all levels of user involvement, allowing growers to work through the program modules in the order and to the stage that suit their business priorities.

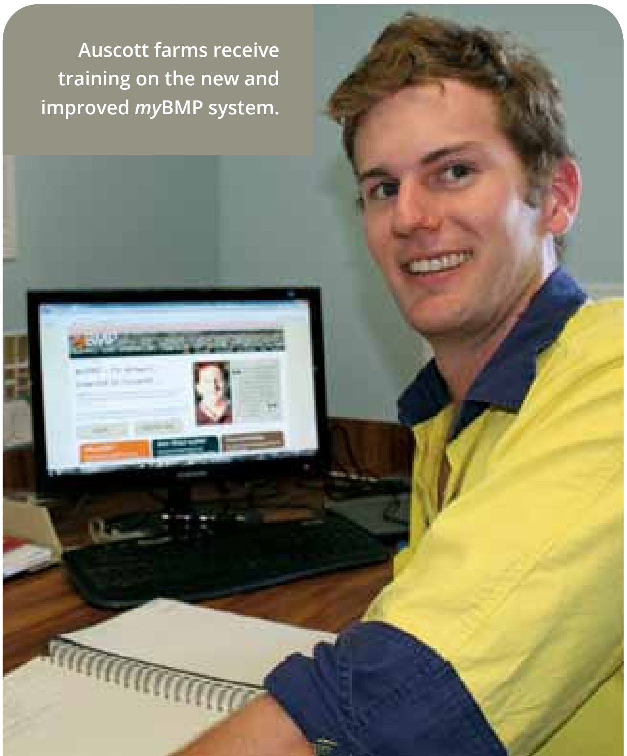
A new system of classification has practices in each of the 13 modules developed into four levels of participation:

LEVEL 1 is the entry level that covers off identified legal requirements.

LEVEL 2 contains what has been determined, by industry as current best practice. Together, these two levels comprise the content required to complete *my*BMP certification.

LEVEL 3 and **LEVEL 4** are aspirational levels that cover those practices that will be considered best practice in the next five and ten years respectively.

Auscott farms receive training on the new and improved *my*BMP system.



The current *my*BMP modules are:

1. Biosecurity
2. Biotechnology
3. Energy and Greenhouse Gases
4. Fibre Quality
5. Human Resources
6. Integrated Pest Management
7. Natural Assets
8. Pesticide Management
9. Petrochemical Storage and Handling
10. Soil Health
11. Water Management
12. Cotton Ginning
13. Cotton Classing

The introduction of *my*BMP brought the challenge of transitioning growers from the old system to the new. The significant changes and improvements meant that extensive support resources were needed to ensure that users could quickly access help with everything from registration all the way through to certification. *my*BMP is extensively supported by the cotton industry Development and Delivery team, whose members come from all areas of industry research and extension. The *my*BMP support team works to make sure all areas of the program continue to function efficiently and effectively, from reviewing the content of each practice to find new or better resources to helping users to get the best from the interactive web-based system.

*my*BMP training with growers at the Australian cotton conference.

John Watson and Ken Flower.

To assist in the rollout of *my*BMP, and under the new D&D framework, which aimed to work more closely with agribusiness, a Certified Advisor Training Program was created to train agribusiness staff to work confidently with any of their clients who would like to participate in *my*BMP. The aim of the program was to train sufficient agribusiness staff to ensure that all key cotton-producing areas have access to *my*BMP certified advisors, who will be available to provide assistance and answer questions.

The *my*BMP Certified Advisor Program began in June 2010, with Cotton Growers Services' staff from Narrabri, Wee Waa, Hillston, Warren and Goondiwindi attending the training. Further training has increased the total number of certified Advisors to 30, representing five different agribusinesses.

More training days are scheduled for 2012 to further increase the number of advisors.

Undertaking *my*BMP provides cotton growers with the confidence that their on-farm practices are legally covered, with Level One practices providing guidelines and practical advice on how to comply with legal requirements ranging from the storage and use of chemicals to the requirements of human resource management.

*my*BMP continues to be received well by end-users, with over 200 growers using the program already and each week bringing new registrations from growers, researchers and industry personnel, who are actively using the tools and resources to find new and better ways to grower cotton.


Landline, ABC radio and NBN catching up on the latest research findings.

Getting it out there

The cotton industry is renowned as the most technologically advanced agricultural industry in Australia, with cotton growers the fastest to adopt emerging technologies and research. It has been the task of the Cotton CRC to enable this adoption with solid science, effectively communicated.

Communication Manager Yvette Cunningham said a cooperative organisation such as the Cotton CRC involves numerous organisations, people and priorities, requiring many communication styles and methods to achieve the best result.

'Communicating our research results is key to its use and uptake, to be effective this involves all members of the CRC community including the D&D team, researchers and program leaders', said Yvette

Our external communication activities had three principal aims:

- Maintain strong relationships with partner and affiliate organisations to keep them involved and informed about CRC activities, through formal advisory committees, workshops, informal gatherings and conference presentations.
- Increase awareness, understanding and adoption of best practice science in relation to cotton production, environmental and catchment management, through workshops, field days, grower meeting, production manuals and guides, end user publications, *my*BMP, CottASSIST and website access.
- Provide industry, government, NRM bodies and community organisations with concise, comprehensive information on current and emerging issues which will help deliver optimum economic, environmental and social benefits, through publications, website access, technical updates and annual reports.

Media campaigns have been a key component of the Cotton CRC communication strategy, aiming to position the CRC as a reliable source of scientific knowledge regarding the Australian Cotton industry, including production, environmental and social research. The CRC has enjoyed international coverage in both print and broadcast media over the last seven years.

The Cotton CRC has contributed significantly to a number of key end-user publications such as CRDC's Spotlight Magazine, CSD's Seed for Thought Newspaper and The Australian Cottongrower Magazine.

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BIG DAY OUT

The Australian Cotton Industry's BIG DAY OUT is a combined initiative of the Cotton CRC and the CRDC, that aims to update past, current and future cotton growers on emerging research and provide growers with the opportunity to get involved in the industry and see the inner workings of a leading farming enterprise first hand. To date, three have been held, with over 130 people attending each:

- 2009: 'Keytah', Moree, NSW
- 2010: Jamie and Susie Grant at 'Kielli', Jimbour Queensland
- 2011: Rob and Susannah Tuck at 'Newhaven', Trangie NSW

EXTERNAL COMMUNICATIONS INCLUDED

- Media Releases
- Displays at conferences and public events
- Annual production manuals
- Contribute to key end-user publications such as The Australian Cottongrower
- Peer-reviewed publications
- Hosting national conferences such as the Sustaining Rural Communities Conference
- Workshops/Field days
- Cotton CRC E-News
- Presentations to key industry, science and management groups
- Annual reports

INTERNAL COMMUNICATIONS INCLUDED

- Cotton Chat E-news
- Annual Science Forum
- Staff lounge on website
- D&D workshops and fortnightly teleconferences
- Milestone six monthly reports
- Project Final reports
- Annual reports
- PhD professional development
- Professional development/team building for staff

The Science Forum - a pivotal part of the Cotton CRC.

Talking to our people

The success of the CRC's program of broad-based, but integrated, participatory research called for its researchers to go beyond state borders and traditional organisational relationships and see themselves as belonging to a Cooperative Research Centre as well as to their employer organisations. Our internal communication activities aimed to make all members feel ownership of the Cotton CRC by:

- ensuring knowledge flowed between researchers, stakeholders and across projects, partners and programs,
- ensuring all students, researchers and extension personnel were aware of upcoming events, professional training, conferences, research activities and outcomes,
- building strong relationships within the CRC and across supporting organisations, to foster collaborative work between participants.

The Annual Science Forum was a major tool to facilitate open communication within the Cotton CRC, where all researchers, postgraduate students, extension staff, Cotton CRC partners and affiliates came together and shared expertise and knowledge as well as to celebrate each year's success. The science forum was made up of:

- facilitated workshop and lecture sessions, based around core research areas,
- media opportunities, encouraging researchers to promote their science to the wider communities,
- dedicated sessions to PhD students, providing them with the opportunity to present their work,
- networking opportunities,
- annual awards night to celebrate success and noteworthy performances.

The Science Forum was a pivotal part of the Cotton CRC and about much more than just the science: it focused on the people and their commitment to their research and the cotton industry, not to mention everyone's willingness to have some fun along the way.

Cotton CRC Awards Annual Science Forum Awards

EXCEPTIONAL CONTRIBUTION OVER THE LIFE OF THE COTTON CATCHMENT COMMUNITIES CRC:

2012
Dr Lewis Wilson (CSIRO)
Kym Orman (Cotton CRC)
Lynda George (Cotton CRC)
David Anthony (Cotton CRC Chair)
Kathryn Adams (Cotton CRC Board)
Prof Peter Gregg (UNE/Cotton CRC)

CRC COMMERCIAL PARTNERSHIPS:

2012
Peter Glennie (BS Glennie & Son)
Dr Robert Mensah (Dept Primary Industries NSW)
Growth Agriculture
AgBitech
Quick Test Technologies
BSE Electronics

SCIENCE AND INNOVATION:

2012
Dr Nancy Schellhorn (CSIRO)
- For her research into pest suppressive landscapes.

2010
Angus Crossan (USYD), Ivan Kennedy (USYD), Shuo Wang (TUST)
- For the development of Quick Test Technology

2009
Graham Charles (NSW DPI)
- For long term achievements in developing weed thresholds and management strategies.

2008
Paul Grundy (DAFF Queensland) and Stephen Yeates (CSIRO)
- For the contributions to the development of the cotton industry in the Burdekin Valley.

2007
Ian Acworth, Anna-Katrin Greve & Bryce Kelly (UNSW)
- For the development of electrical imaging techniques for soil water

SCIENTIFIC PAPER:

2012
Dr James Quilty (USYD) and Dr Stephen Cattle (USYD)
'Use and understanding of organic amendments in Australian agriculture: a review. Soil Research Vol 49 Pg 1-26'

2010
Greg Constable, Robert Long, Michael Bange, Stuart Gordon (all CSIRO)
'Measuring the Maturity of Developing Cotton Fibres using an Automated Polarized Light Microscopy Technique'

2009
Richard Sequeira (DAFF Queensland)
'Sampling and management of Bemisia tabaci (Genn.) biotype B in Australian cotton. Published in Crop Protection 27, 1262-1268.'

2008
Angela McDowell (USYD), Daniel Tan (USYD), Michael Bange (CSIRO)
'Cold temperature exposure at 10^{o}C for 10 and 20 nights does not reduce tissue viability in vegetative and early flowering cotton plants' published in The Australian Journal of Experimental Agriculture, 47,198-207,2007'

2007
Michael Rose , Fancisco Sanchez-Bayo, Angus Crossan, Ivan Kennedy (All USYD)
'Pesticide removal from cotton farm tailwater by a pilot-scale ponded wetland, published in Chemosphere 63, 1849 – 1858'

IMPACT IN ADOPTION:

2012

Sandra Williams (CSIRO)

- For ongoing support of myBMP

2010

Stacey Vogel (Namoi CMA)

- For dedication to the Namoi CMA onground works project

2009

Sally Ceeney (NSW DPI)

- For her dedication and persistence in servicing on ground industry needs

Susan Maas (DAFF Queensland)

- For her dedication and persistence in servicing on ground industry needs.

2008

Jane Macfarlane (Namoi CMA), Ingrid Rencken (DAFF Queensland) and Veronica Chapman (DAFF Queensland)

- For the Biodiversity in Cotton Landscapes 2008 Calendar

2007

Rene van der Sluijs and the CSIRO Textile & Fabric Technology team

- For the Cotton Field to Fabric Training Course

CONTRIBUTION TO PhD SUPERVISION:

Chris Guppy, UNE

Daniel Tan, USYD

Willem Vervoort, USYD

Nick Reid, UNE**COLLABORATION & CORPORATE CITIZEN:**

2012

Extension Re-Bid Team:

Dr Michael Bange, CSIRO Plant Industry

Mark Hickman, DAFF Queensland

Jane Trindall, Cotton CRC

Dr Anthony Hogan, Australian National University

Dr Guy Roth, Roth Rural & Regional

Prof Peter Gregg, UNE/Cotton CRC

2010

Geoff MacIntyre (DAFF Queensland)

- For dedication to extension and Industry

2009

Trudy Staines (Cotton CRC)

- For facilitating collaboration between diverse contributors to achieve outcomes in school education.

John Stanley (UNE)

- For facilitating collaboration between diverse contributors to achieve outcomes in university education.

Lewis Wilson (CSIRO)

- For exceptional contributions to the management of the CRC, and for outstanding achievements in research and extension.

2008

Rene van der Sluijs, Shouren Yang, Stuart Gordon Geoff Naylor (CSIRO)

- For outstanding efforts in International collaboration.

2007

Tracey Leven (NSW DPI)

- For outstanding efforts in establishing and fostering the CRC project High Yielding Irrigated Grains in Cotton Farming Systems

David Nehl, NSW DPI

- In appreciation of his exceptional service to successive Cotton CRCs and to the cotton industry


Australia

www.cottoncrc.org.au

The Cotton CRC Technology Resource Centre (TRC) has been the centre of information distribution and a key player in the success of our Education and Adoption Programs. It presents the outcomes of research, assisting with the development, distribution and adoption of all research products, including written extension materials, decision support manuals such as the cotton 'paks' and, primarily, the Cotton CRC website, which is the cornerstone of research and extension information.

TRC coordinator David Larsen said the website is the major conduit for production, environmental and social research to end users across the Australian cotton industry. It evolved from the production-based content of the Australian Cotton CRC to a three-tiered site showcasing research findings and tools from across the Farm, Catchment, Community and Product Program areas.

'We used a Content Management System to redevelop the site, which enabled the repurposing of information to create a more interactive experience for our visitors', says Dave.

'We had the scope to take all of our hard copy ID guides, such as the Weed ID, Pest and Beneficial Guide, Birds on Cotton Farms, Fish and Grass IDs, and transform them into interactive web tools that link the identification with management and further information. This new innovative and creative approach allowed us to more than double visitors to our site (Figure 3), averaging 7000 unique hits a month'.

Access to the Cotton CRC website will be made available until 2015, hosted by CSIRO, with NSW DPI support. Leading up to this time, information will be transferred to the Cotton Research and Development Corporation industry portal.

Figure 3. Birds on Cotton Farms ID tool and Fishes on Cotton Farms interactive guide.

Top web pages

- Weed ID page
- Insect Pest ID Guides
- Water management
- Cotton facts
- Cotton economics
- Community Wellbeing & Cotton Production in the MDB

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CottASSIST the best science - the best solution

Growing a good crop of cotton often involves the need to make many difficult and complex decisions. To help with these, crop managers across Australia have access to a suite of continually-updated web tools.

CottASSIST, a suite of online tools developed by the Cotton CRC and CSIRO, enables cotton farmers and their consultants to identify nutritional requirements, assess growth against expected standards, and evaluate the need for pest control for timely decisions based on their own crop, soils and climatic information. These tools have been pivotal in the adoption of Cotton CRC research, providing science-backed support and validation of in-crop management decisions.

CottASSIST tools evolved from CottonLOGIC, which began as a desktop program in the late 1990s and focused on supporting pest management decisions. As the worldwide web developed and the need for assistance with other aspects of crop management grew, so our tools evolved into CottASSIST, which became a convenient, continually updated suite of online tools available free to the Australian cotton industry.

Use of CottASSIST has grown rapidly since its launch in 2008, with 657 registered users to date, and comprises the following tools.

Crop Development Tool (CDT)

Cotton development can be predicted using daily temperature data (day degrees). The CDT uses this data to enable crop managers to check the vegetative and reproductive growth of crops compared to expected rates of growth and development under those conditions. This information can be used to further explore why the crop may or may not be on track and then manage accordingly. This tool was developed in collaboration with CSIRO researchers Dr Michael Bange, Dr Greg Constable and the Cotton Seed Distributors extension team.

Day Degree Report

Keeping track of day degree accumulation is widely used to identify the progress towards a cotton development stage: e.g., first square (a flower bud) or first flower. The Day Degree Report predicts crop progress through the season using local weather data and sowing time and compares progress with other years using historical climate data.

Last Effective Flower Tool (LEFT)

LEFT predicts the date after which a flower is no longer likely to have sufficient time to complete development into an open boll. Predicting this date can be used to manage a cotton crop to ensure harvest timeliness and avoid wet and cool weather. This is particularly important for picking good quality cotton. This tool was developed in collaboration with CSIRO researcher Dr Michael Bange.

Helicoverpa Diapause Induction and Emergence Tool (DIET)

Using local day length and temperature data, the DIET can predict the percentage of *Helicoverpa armigera* pupae going into diapause and when these are likely to emerge as moths. This information can be used to refine decisions for effective pupae busting. This tool was developed in collaboration with the Queensland Department of Employment, Economic Development and Innovation (DAFF Queensland).

Aphid and Mite Yield Loss Estimators

Manual calculations of yield loss from pest infestations are complicated and time consuming. This tool allows the user to enter current aphid or mite samples to estimate a rate of pest increase and the potential effect on yield. This allows crop managers to 'look ahead' to decide whether these pests require control, or whether natural enemy populations are providing sufficient control. These tools were developed in collaboration with CSIRO researcher Dr Lewis Wilson.

NutriLOGIC

Optimising yield, reducing fertiliser costs and minimising greenhouse gas emissions are important considerations for cotton production. NutriLOGIC uses information collected from soil, petiole, and leaf tests to generate optimal fertiliser recommendations by interpreting levels of major and minor nutrients needed for production. This tool was developed in collaboration with CSIRO researcher Dr Ian Rochester.

Seasonal Climate Analysis

Climate variability challenges all aspects of farming in Australia and cotton production is no exception. This tool can help analyse seasonal variability or regional influences on crop performance by comparing rainfall, day degrees, number of cold and hot days with long-term averages and probabilities.

Silverleaf Whitefly (SLW) Threshold Tool

This tool allows users to enter regular sampling information to track the development of SLW populations over time. The tool then compares these populations with the control thresholds which are based on the pest population size, day degrees and crop stage. This tool was developed in collaboration with Emerald-based researcher Richard Sequeria and extension officer Susan Maas (both with DAFF Queensland).

Water Quality Calculator

Poor quality water potentially has an impact on cotton yield. This tool helps calculate the water quality resulting from mixing water from different sources and highlights the potential impact that this water quality may have on cotton yield.

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Turning knowledge into policy

Building the capacity and scientific basis on which government and catchment management bodies base investment and management decisions has been a critical component of the adoption and commercialisation strategy. The Cotton CRC Adoption Program combined forces with the Catchment and Communities program to lead cross sector activities to inform policy makers.

In 2010, Jane Trindall (Catchment Program leader), with the help of Yvette Cunningham (Adoption Program leader), worked with the Namoi Catchment Management Authority to organise the inaugural Namoi Valley Groundwater Forum. The purpose was to share knowledge and research that illustrated the importance of groundwater to the environment and economy of the Namoi valley. The forum gave attendees a clearer understanding of current groundwater issues and research, the direction of groundwater management and future trends.

Representatives from government, universities, industry research funding bodies and research organisations attended, representing the mining, natural resource management and agricultural sectors. The forum explored the opportunities for an integrated approach to groundwater investigation, including how agriculture, gas and mining affect groundwater dynamics and quality.

Following on from the success of this event, the Cotton CRC joined forces with Cotton Australia and CRDC to hold 'Australian Cotton Water Story – a research review' which synthesised the outcomes of all cotton water research from the paddock to the community scale. The aim of the Water Story was to take stock of the breadth of cotton water R&D that has taken place over the past decade, highlight the successes, articulate the legacy of the Cotton CRC and set the strategic direction for industry investment in water research for the coming years.

The Communities program undertook several activities aimed at better informing policy makers. A report entitled ***'Social and Economic Impacts of Reduced Irrigation Water'*** aimed to describe and predict the potential social and economic impacts which may arise from changes in water availability in the Murray Darling Basin. Due to the importance of this study, the body of work underwent two independent peer reviews, ensuring that the report could provide relevant impartial science into the debate on changing water availability in regional communities.

In addition to this work, the Sustaining Rural Communities Conferences, an initiative of Dr Paula Jones provided a platform to showcase, discuss and act upon the broad range of social research currently being undertaken in rural communities.

these are OUR people


HYDRANT &
HOSE


AUSTRALIA


these are
OUR
people

Organisation Affiliations

A CRC can only exist because of the collaboration that comes from individuals who give their intellect and commitment without constraint or limitation.
The Cotton CRC has always believed that its people were at the heart of its success. It is the relationships built within and beyond the CRC that ensured goals were met, solutions found, sound collaborative research conducted and considerable goodwill amassed.

Many key people have been identified throughout this book. A complete list of all those involved in the CRC – including board members, cotton growers and consultants, partner and affiliate organisations, researchers, students and stakeholder representatives – appears below. But there are many more people who are not mentioned, nor formally recognised, for the contribution that they have made over the life of this and previous Cotton CRCs.
We offer a broad thank you also to these people.

LEGEND FOR THE ORGANISATION AFFILIATIONS

Aboriginal Employment Strategy	**AES**
Australian National University	**ANU**
Aquatech Consulting Pty Ltd	**ATC**
Border River Gwydir Catchment Management Authority	**BR&G CMA**
Centre for Agricultural & Regional Economics	**CARE**
Border River Gwydir Catchment Management Authority	**BR&G CMA**
Central Queensland University	**CQU**
Charles Sturt University	**CSU**
Central West Catchment Management Authority	**CWCMA**
Cotton Australia	**CA**
Cotton Catchment Communities CRC	**Cotton CRC**
Cotton Seed Distributor	**CSD**
Cotton Research and development Corporation	**CRDC**
CRC for Irrigation Futures	**CRC IF**
CSIRO	**CSIRO**
Eco Logical Australia Pty Ltd	**EcoLA**
Greening Australia Ltd	**GA**
Department of Agriculture and Food, Western Australia	**DA&F WA**
DuPont Crop Protection	**DCP**
NSW Department	**NSW DE&W**
Department of Agriculture and Food, Western Australia	**DA&F WA**

LEGEND FOR THE ORGANISATION AFFILIATIONS

Griffith University	**GU**
Inverell Shire Council	**ISC**
Judith Stubbs & Associates	**JS&A**
La Trobe University	**LaT Uni**
Narrabri Shire Council	**NSC**
Narromine Shire Council	**NMSC**
Namoi Catchment Management Authority	**Namoi CMA**
New England North West Landcare Network Chairs	**NE NW LNC**
University of South Australia	**UNI SA**
NSW Department of Primary Industries	**NSW DPI**
NSW Farmers Association	**NFA**
NSW Office of Water	**NSW OW**
NT Dept Primary Industries, Fisheries & Mines	**NTDPIFF**
Southern Cross University	**SCU**
Sustainable Soils Management Pty Ltd	**SSM**
Terrabyte Services Pty Ltd	**TS**
The University of Sydney	**USYD**
The State of Queensland acting through the Department of Employment, Economic Development and Innovation	**DAFF Queensland**
The University of New England	**UNE**
The State of Queensland as Represented by Department of Environment & Resource Management	**QDERM**
Tianjin University of Science & Technology	**TUST**
University of Canberra	**UC**
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Cotton Catchment Communities Cooperative Research Centre

PARTICIPANTS CASH CONTRIBUTIONS, OTHER FIRM CASH AND CRC PROGRAM FUNDING ($'000S)

	2005-06 ACTUAL	2006-07 ACTUAL	2007-08 ACTUAL	2008-09 ACTUAL	2009-10 ACTUAL	2010-11 ACTUAL	2011-12 PROJECTED	TOTAL
CORE PARTICIPANTS								
Australian Cotton Growers Research Association Inc	36	70	66	27	18	0	0	217
Cotton Australia Limited	0	687	216	330	53	136	0	1,422
Cotton Research & Development Corporation	3,993	4,190	3,881	3,597	3,568	3,682	4,000	26,911
Cotton Seed Distributors Limited	50	50	50	50	50	50	50	350
The University of New England	105	100	50	50	50	50	50	455
University of New South Wales	100	100	100	100	100	100	100	700
University of Sydney	100	100	100	75	125	75	125	700
University of Technology Sydney	50	50	50	50	50	50	50	350
TOTAL CORE PARTICIPANTS' CASH	4,434	5,347	4,513	4,279	4,014	4,143	4,375	31,105
SUPPORTING PARTICIPANTS								
Ag Biotech Australia Pty Ltd	50	50	50	13	26	11	0	200
Aquatech Consultants Pty Ltd	5	5	5	5	5	5	6	36
Australian Cotton Shippers Association	28	20	37	43	31	28	20	207
Australian National University	0	100	50	0	0	0	0	150
Central West Catchment Management	0	5	70	0	16	16	0	107
Charles Sturt University	0	0	12	9	3	0	0	24
Condamine Catchment Natural Resource Management Corporation Ltd	10	118	177	49	0	0	0	354
Cotton Consultants Australia Inc	2	3	2	1	0	0	0	8
Department of Environment and Resource Management (DERM) (QLD) *(formerly Queensland Department of Natural Resources and Mines)*	0	0	0	0	56	142	0	198
Dunavant Enterprises Pty Ltd	20	20	20	20	0	0	0	80
Grains Research and Development Corporation	48	256	252	514	0	480	250	1,800
Greening Australia Ltd	0	0	10	0	0	0	0	10
Incitec Pivot Limited	48	96	0	0	0	0	0	144

	2005-06 ACTUAL	2006-07 ACTUAL	2007-08 ACTUAL	2008-09 ACTUAL	2009-10 ACTUAL	2010-11 ACTUAL	2011-12 PROJECTED	TOTAL
INTERNATIONAL FIBRE CENTRE LIMITED	69	53	28	0	0	0	0	150
Inverell Shire Council	5	5	5	0	0	0	0	15
Millmerran Shire Council	5	5	0	0	0	0	0	10
Monsanto Australia Ltd	44	25	0	0	96	63	0	228
Namoi Catchment Management Authority	160	1,459	413	195	0	7	0	2,234
Narrabri Shire Council	30	30	30	30	15	15	0	150
Narromine Shire Council	2	2	0	0	0	0	0	4
Orica Australia Pty Ltd	0	33	33	33	8	0	0	107
Other Participants (not core or supporting) - Cotton 20040073	0	0	0	0	0	230	0	230
Queensland Murray Darling Committee	0	0	50	70	0	7	0	127
Sunwater	0	0	40	40	40	0	0	120
Telstra Corporation Limited	5	5	1	0	0	0	0	11
The University of Queensland	50	50	50	50	50	50	50	350
TOTAL SUPPORTING PARTICIPANTS' CASH	581	2,340	1,335	1,073	346	1,054	326	7,055
OTHER CASH								
Other Cash Resources	1,353	1,396	2,104	1,299	726	311	0	7,189
CRC Program Funding	3,500	4,000	4,500	4,000	4,000	3,500	3,000	26,500
TOTAL OTHER CASH	4,853	5,396	6,604	5,299	4,726	3,811	3,000	33,689
TOTAL CASH	9,868	13,083	12,452	10,651	9,086	9,008	7,701	71,849

Cotton Catchment Communities Cooperative Research Centre

TOTAL IN-KIND ($'000S) (PER PARTICIPANT) STAFF & NON-STAFF

	2005-06 ACTUAL	2006-07 ACTUAL	2007-08 ACTUAL	2008-09 ACTUAL	2009-10 ACTUAL	2010-11 ACTUAL	2011-12 PROJECTED	TOTAL
CORE PARTICIPANTS								
Australian Cotton Growers Research Association Inc	1,225	717	1,044	1,503	1,252	1,009	0	6,750
Cotton Australia Limited	646	485	734	742	442	190	190	3,429
Cotton Research & Development Corporation	784	1,006	1,058	1,047	1,106	1,177	767	6,945
Cotton Seed Distributors Limited	0	709	747	661	678	717	717	4,229
CSIRO	1,978	3,579	3,304	3,087	2,938	3,234	3,009	21,129
Department of Agriculture and Food *(formerly WA Department of Agriculture)*	524	491	277	0	95	0	0	1,387
Department of Employment, Economic Development & Innovation QLD *(formerly Dept of Primary Industries and Fisheries (QLD)*	1,982	2,446	2,499	2,291	2,280	2,076	1,589	15,163
NSW Department of Primary Industries *trading as the Department of Industry and Investment*	1,661	2,984	3,490	2,934	2,616	2,145	1,455	17,285
The University of New England	1,686	1,590	1,767	2,230	1,922	1,231	1,204	11,630
University of New South Wales	183	322	689	847	768	454	369	3,632
University of Sydney	1,111	1,901	1,392	637	430	267	180	5,918
University of Technology Sydney	222	196	161	52	90	67	17	805
TOTAL CORE PARTICIPANTS	12,002	16,426	17,162	16,031	14,617	12,567	9,497	98,302
SUPPORTING PARTICIPANTS								
Ag Biotech Australia Pty Ltd	122	54	25	82	99	84	104	570
Aquaculture Association of Queensland Inc.	10	0	0	0	0	0	0	10
Aquatech Consultants Pty Ltd	44	51	14	5	47	47	0	208
Australian Cotton Trade Show Trust	0	8	0	0	0	0	0	8
Australian National University	22	114	168	126	96	282	388	1,196
Border River Catchment Management Authority	0	5	0	0	0	11	15	31
Boyce Chartered Accountants	40	0	0	0	0	0	0	40
Central Queensland University	0	65	129	234	126	15	0	569
Central West Catchment Management	0	0	8	27	72	48	25	180

	2005-06 ACTUAL	2006-07 ACTUAL	2007-08 ACTUAL	2008-09 ACTUAL	2009-10 ACTUAL	2010-11 ACTUAL	2011-12 PROJECTED	TOTAL
SUPPORTING PARTICIPANTS cont.								
Charles Sturt University	12	52	68	52	0	50	51	285
Conservation Farmers Inc.	0	0	5	0	0	0	0	5
Cotton Consultants Australia Inc	127	0	0	0	0	8	0	135
Department of Environment and Resource Management (DERM) (QLD) *(formerly Queensland Department of Natural Resources and Mines)*	352	379	450	484	448	286	75	2,474
Department of Infrastructure, Planning and natural Resources	0	176	141	109	142	10	0	578
Greening Australia Ltd	0	0	19	0	0	0	0	19
Griffith University	18	0	18	0	0	12	160	208
Incitec Pivot Limited	0	65	0	0	12	0	0	77
La Trobe University	20	48	48	11	0	0	0	127
Monsanto Australia Ltd	0	0	0	0	15	80	0	95
Namoi Catchment Management Authority	246	354	541	339	176	178	111	1,945
Queensland Murray Darling Committee	0	13	13	15	66	66	0	173
Southern Cross University	51	0	0	0	0	0	147	198
Sustainable Irrigation Systems	29	0	0	0	0	0	0	29
Telstra Corporation Limited	0	2	0	0	0	0	0	2
Terrabyte Services Pty Ltd	0	0	53	108	116	0	0	277
The University of Adelaide	32	0	22	4	5	0	0	63
The University of Queensland	74	112	148	148	80	53	57	672
TOTAL SUPPORTING PARTICIPANTS	1,199	1,498	1,870	1,744	1,500	1,230	1,133	10,174
OTHER IN-KIND RESOURCES	114	77	305	457	1,248	1,018	1,967	5,186
GRAND TOTAL	**13,315**	**18,001**	**19,337**	**18,232**	**17,365**	**14,815**	**12,597**	**113,662**

Publications report

Books

Kennedy IR, Solomon KR, Gee SJ, Crossan AN, Wang S & Sanchez Bayo, F (2007).

Rational Environmental Management of Agrochemicals: Risk Assessment, Monitoring, and Remedial Action.

ACS Symposium Series No. 966. Oxford University Press, Washington DC, USA.

Townsend A, Jenkins C, Baker L, Roth G, MacFarlane J, Faris J, Hawkins P, Stephens B, Clements J, Williams T, Staines C, Ping-Kee R & Hobson, M (2009)

Fishes on Cotton Farms: A Guide to Native Fish and Habitat Management for North-West NSW, Industry & Investment NSW and Cotton Catchment Communities CRC, Narrabri, Australia.

Yeates S, Moulden J, Strickland G & Davies A. (2007). NORpak - Ord River Irrigation Area Cotton Production and Management guidelines for the Ord River Irrigation Area (ORIA). CSIRO, Canberra, Australia.

Book chapters

Andow DA , Fitt GP, Grafius EJ, Jackson RE, Radcliffe EB, Ragsdale DW, & Rossiter L. (2008)

Pesticide and transgenic plant resistance management in the field.

In Whalon, ME, Mota–Sanchez, D & Hollingworth R M. Global Pesticide Resistance in Arthropods CABI, Publishing, UK, 118-144.

Andow DA, Nguyen VT, Hilbeck A, Underwood E, Birch AN, Depicker A, Dinh QT, Fitt GP, Giband M, Johnston J, Lang A, Le QQ, Le TT, Lovei GL, Nelson KC, Nguyen,HS, Nguyen HH, Nguyen TH, Nguyen TT, Nguyen VH, Nguyen VU, Pham VL, Pham VT, Sijii ER, Tran AH, Tran TC, Vu DQ, Wheatley RE & Wilson L.J. (2008).

Challenges and opportunities with Bt cotton in Vietnam: Synthesis and recommendations, In Andow, DA, Hilbeck A and Tuat N. van (eds.) Environmental risk assess of GM organisms: Challenges and opportunities with Bt cotton in Vietnam.

CABI Publishing, UK, 330-344.

Bange MP, Constable GA, McRae D & Roth G. (2010).

Cotton. In Stokes C and Howden M. (eds.) Adapting agriculture to climate change: preparing Australian agriculture, forestry and fisheries for the future.

CSIRO Publishing, Collingwood, Australia, 49-66.

Coumans JVF & Backhouse D. (2010).

Protein analysis of abiotic and biotic stress response during cotton vegetative growth. In Jenkins PT (ed.) The Sugar Industry and Cotton Crops.

Nova Science Publishers, Inc., New York, 127-145.

Crossan AN, Rose MT & Kennedy IR. (2007)

Pesticide risk reduction by management practices - An environmental case study of the Australian cotton industry. In Kennedy IR, Solomon KR, Gee SJ, Crossan AN, Wang S and Sanchez Bayo F (eds.) Rational Environmental Management of Agrochemicals: Risk Assessment, Monitoring, and Remedial Action.

ACS Symposium Series No. 966. Oxford University Press, Washington, USA.

Fitt G & Cotter S (2005).

The Helicoverpa Problem in Australia: biology and management. In Sharma, H. (ed.) Heliothis/Helicoverpa management- emerging trends and strategies for future research.

Science Publishers Incorporated, New Hampshire, 45-61.

Fitt G, Omoto C, Maia AH, Waqil J, Caprio M, Dennehy T, Okech M, Alves Z, Cia E, Nguyen H & Andow DA (2005)

Resistance risks of Bt cotton and their management in Brazil. in Hilbeck A & Andow D (eds.) Environmental Risk Assessment of Transgenic Organisms: A Case Study of Bt Cotton in Brazil.

CAB International, Wallingford, Oxon, UK. 300-345.

Fitt GP, Andow DA, Nguyen HH, Caprio M, Omoto C, Nguyen T, Nguyen HS, & Bui CT (2008)

Resistance risk assessment and management for Bt cotton in Vietnam. In Andow DA, Hilbeck A & Van Tuat N. (eds.) Environmental Risk Assessment of Genetically Modified Organisms: Challenges and Opportunities with Bt Cotton in Vietnam.

CABI Publishing, UK 296-329.

Fitt GP (2008)

Have Bt crops led to changes In insecticide use patterns and impacted IPM? In .Romeis J, Shelton AM & Kennedy GG(Eds.) Integration of insect-resistant GM crops within IPM Programs.

Springer Science and Business Media BV, Philadelphia, 303-328.

Fitt GP, Wilson LJ, Kelly D & Mensah RK (2009).

Advances in integrated pest management as a component of sustainable agriculture: The case study of the Australian cotton Industry. In Peshin R. & Dhawan AK (eds.) I ntegrated Pest Management: Innovation – Development.

Springer Science and Business Media BV, Philadelphia, 507-524.

Gupta VVSR. & Knox, OGG (2010)

How best can we design rhizosphere plant-microbe interactions for the benefit of plant growth? In: Gupta VVSR, Ryder MM & Radcliffe J. (eds.)The Rovira Rhizosphere Symposium - Celebrating 50 years of rhizosphere research.

The Crawford fund, Deakin, ACT, Australia. 11-24,

Gurr GM, Price PW, Urrutia M, Wade M, Wratten SD & Simmons AT (2007).

Ecology of predator-prey and parasitoid-host systems: Its role in IPM. In Koul E. & Cuperus GW (eds.) Ecologically based Integrated Pest Management.

CAB International, Wallingford, 222-248.

Gurr GM, Wratten SD, Tylianakis J, Kean J & Keller M (2005).

Providing plant foods for natural enemies in farming systems: Balancing practicalities and theory. In Wackers FL, Van Rijn PCJ & Bruin J (eds.) Plant-Provided Food for Herbivore- Carnivorous Insects: a Protective Mutualism and its Applications.

Cambridge University Press, Cambridge, UK, 326-347.

Publications report

Hilbeck A, Arpaia S, Birch AN, Chen Y, Fontese EM, Lang A, Le TT, Lovei G, Manachini B, Nguyen TT, Nguyen VH, Nguyen VT, Pham VL, PhamVT, Pires C, Sujii E, Trac KL, Underwood E, Wheatle, R, Wilson LJ, Zwahlen C & Andow DA (2008).

Non-target and biological diversity risk assessment. In Andow DA, Hilbeck A & Van Tuat N. (eds.), Environmental risk assessment of GM organisms: Challenges and opportunities with Bt cotton in Vietnam.

CABI Publishing, UK, 115-137.

Hollingsworth B, Odeh IE, Ludwig J & McLeod P. (2007).

Rule based Land Unit Mapping of the Tiwi Island. In Lagacherie P, McBratney AB & Voltz M (eds.) Digital Soil Mapping.

Elsevier, Amsterdam. 401-414.

Hulugalle NR, Weaver TB & Ghadiri H (2006).

A simple method to estimate the value of salt and nutrient leaching in irrigated Vertisols in Australia. In Cano FA.,Silla OR & Mermut AR (eds.) Sustainable use and Management of Soils - Arid and Semiarid Regions.

Catena Verlag; Reiskirchen; Germany, 579-588.

Hulugalle, NR,& Daniells IG (2005).

Permanent beds in Australian cotton production systems. In Roth CH, Fisher RA, & Meisner CA (eds.) Evaluation and Performance of Permanent Raised Bed Cropping Systems in Asia, Australia and Mexico.

ACIAR, Canberra, Australia. 161-171.

Kelleway J, Mazumder D, Wilson GG & Kobayashi T (2010).

Using isotopic techniques to assess trophic structure in northern Murray-Darling Basin wetlands. In Saintilan N & Overton I. (eds) Ecological Response Modelling in the Murray-Darling Basin.

CSIRO Press, Melbourne. Pp 85-101.

Mensah RK & Pyke BA (2007).

Beneficial insects in cotton in Australia In: Bailey, PT (ed.) Insects of Australian Field Crops and Pastures.

CSIRO Publications, Canberra, Australia, 102-119.

Naranjo SE, Ruberson JR, Sharma HC, Wilson LJ & Wu K (2008).

The present and future role of insect-resistant GM crops in cotton IPM. In Romies J, Shelton AM & Kennedy GG (eds.) Integration of insect-resistant GM crops within IPM programs.

Springer Science and Business Media BV, Philadelphia, 158-194.

Nehl DB & Knox OG (2006).

Significance of bacteria in the rhizosphere. In Mukerji, KG, Manoharachary C & Singh J. (eds.) Soil Biology - Microbial Activity in the Rhizosphere

Springer-Verlag, Berlin, 89-119.

Nguyen TT, Suji ER, Wilson LJ, Underwood E, Andow,DA, Mai VH, Zhai B & Ho VC (2008).

Potential effect of transgenic cotton on non-target herbivores in Vietnam. In Andow DA, Hilbeck A & Van Tuat N. (eds.) Environmental risk assessment of GM organisms: Challenges and opportunities with Bt cotton in Vietnam.

CABI Publishing, UK, 138-175.

Odeh IOA (2008).

Soil variation. In Chesworth (ed.): Encyclopaedia of Soil Science.

Springer, Leipzig Germany: 705-707.

Odeh IOA, Crawford M & McBratney AB (2007).

Digital mapping of soil attributes for regional and catchment modelling, using ancillary covariates, statistical and geostatistical techniques. In Lagacherie P, McBratney AB & Voltz M. (eds.) Digital Soil Mapping.

Elsevier, Amsterdam: 437-453.

Peshin R, Bandrai RS, Zhang W, Wilson LJ & Dhawan, A (2009)

Integrated pest management: A global overview of history, programs and adoption. In Peshin R. & Dhawan A. Integrated Pest Management: Innovation - Development.

Springer Science and Business Media BV, Philadelphia, 1-49.

Powell S, Norton JP & Jakeman AJ (2008).

Model development and analysis, In Jorgensen, SE & Fath, B. (eds.) Encyclopedia of Ecology.

Elsiever, Oxford.

Roth GW (2011).

The cotton industry social licence. In Williams J & Martin P. (eds.) Defending the Social Licence of Farming. Issues, Challenges and New Directions for Agriculture.

CSIRO Publishing. Melbourne. 69-82.

Silburn DM & Kennedy IR (2007).

Rain simulation to estimate pesticide transport in runoff. In Kennedy IR, Solomon KR, Gee SJ, Crossan AN, Wang S & Sanchez Bayo F (eds.) Rational Environmental Management of Agrochemicals: Risk Assessment, Monitoring and Remedial Action.

ACS Symposium Series No. 966, American Chemical Society, Washington, USA, 120-135.

Taylor JA & Odeh IOA (2007).

Comparing discriminant analysis with binomial logistic regression, regression kriging and multi-indicator kriging for mapping salinity risk in northwest New South Wales, Australia. In: Lagacherie P, McBratney AB & Voltz M (eds.) Digital Soil Mapping.

Elsevier, Amsterdam: 455-464.

Tylianakis J, Gurr GM & Wratten SD (2005).

Insect Interactions with other pests (weeds, pathogens, nematodes), In Encyclopaedia of Plant and Crop Science.

Marcel Dekker, New York, USA.

Wang X, Tang C, Guppy CN &Sale PWG (2012)

Phosphorus acquisition characteristics of cotton plants. In Giuliano B & Vinci EJ (eds.) Cotton: Cultivation, Varieties and Uses)

Nova Science Publishers.

Wilson GG, Spencer JA & Heagney E.(2010).

Responses of fish and waterbirds to flow variability in the Gwydir wetlands. In Saintilan N & Overton I. (eds) Ecological Response Modelling in the Murray-Darling Basin.

CSIRO Press, Melbourne. 103–118

Wilson LJ, Fitt GP, Deutscher S, Khan M & Pyke BA(2007).

Cotton pests. In Bailey PT (ed.). Pests of Field Crops and Pastures: Identification and Control

CSIRO Publishing, Melbourne, Victoria. 63 – 119.

Wratten SD, Gurr GM, Tylianakis J & Robinson KA (2007).

Cultural Control of Aphids. In Van Emden HF & Harrington R. (eds.) Aphids as Crop Pests.

CAB International, Wallingford, UK. 423-445.

Wratten SD, Hochuli D, Gurr GM, Tylianakis, J & Scarratt SL (2007).

Conservation, biodiversity and integrated pest management, In Kogan, M. and Jepson, P. (eds.) Perspectives in Ecological Theory and Integrated Pest Management.

Cambridge University Press, Cambridge, UK, 223-245.

Publications report

Refereed journal articles

Abbott AM, Higgerson GJ, Long RL, Lucas SR, Naylor GRS, Tischler CR & Purmalis MM (2010).

An instrument for determining the average fiber linear density (fineness) of cotton lint samples.

Textile Research Journal 80, 822-833.

Acworth RI (2007).

Measurement of vertical environmental-head profiles in unconfined sand aquifers using a multi-channelled manometer board.

Hydrogeology Journal 15, 1279-1289.

Acworth RI (2009).

Surface water and groundwater: understanding the importance of their connections.

Australian Journal of Earth Sciences 56, 1-2.

Acworth RI & Timms WA (2009).

Evidence for connected water processes through smectite-dominated clays at Breeza, NSW.

Australian Journal of Earth Sciences 56, 81-96.

Al Dabel F, Mensah RK & Frerot B (2008).

Effects of nC24 and nC27 petroleum spray oils on oviposition and egg survival of Ostrinia nubilalis Hubner (Lepidoptera: Pyralidae) and Trichogramma brassicae Bezdenko (Hymenoptera, Trichogrammatidae) adults on maize plants.

International Journal of Pest Management 54, 5-11

Ali A, Reddall A, Roberts J, Wilson L & Rezaian M (2007).

Cytopathology, mode of aphid transmission and search for the causal agent of Cotton Bunchy Top disease.

Journal of Phytopathology 155, 220-227.

Ancev T (2006).

Determining the economic value of water: Concepts and methods.

Australian Journal of Agricultural and Resource Economics 50, 115-118.

Andersen MS & Acworth RI (2009).

Stream-aquifer interactions in the Maules Creek catchment, Namoi valley, NSW, Australia.

Hydrogeology Journal 17, 2005-2021.

Anderson CMT, McGee PA, Nehl DB & Mensah RK (2007).

The fungus Lecanicillium lecanii colonises the plant Gossypium hirsutum and the aphid Aphis gossypii.

Australasian Mycologist 26, 65 – 70.

Bahar H, Mensah RK, Backhouse D & Gregg P (2011).

Efficacy of a Cladosporium sp. fungus against Helicoverpa armigera (Lepidoptera: Noctuidae), other insect pests and beneficial insects of cotton.

Biocontrol Science and Technology 21, 1387 - 1397.

Bahar MH, Stanley JN, Gregg PC, Del Socorro AP, & Kristiansen P (2011)

Comparing the predatory performance of green lacewing on cotton bollworm on conventional and Bt cotton.

Journal of Applied Entomology.

Baker GH, Tann CR & Fitt GP (2011).

A tale of two trapping methods: Helicoverpa s (Lepidoptera, Noctuidae) in pheromone and light traps in Australian cotton production systems.

Bulletin of Entomological Research 101, 9-23.

Baker GH, Tann CR & Fitt GP (2008).

Production of Helicoverpa s (Lepidoptera, Noctuidae) from different refuge crops to accompany transgenic cotton plantings in eastern Australia.

Australian Journal of Agricultural Research 59, 723-732.

Bajgai Y, Kristiansen P, Hulugalle N, & McHenry M. (2011).

A laboratory study of soil carbon dioxide emissions in a Vertisol and an Alfisol due to incorporating corn residues and simulating tillage.

Journal of Organic Systems 6, 20-26.

Bange MP, Carberry PS, Marshall J. & Milroy SP (2005).

Row configuration as a tool for managing rain-fed cotton systems: review and simulation analysis.

Australian Journal of Experimental Agriculture 45, 65-77.

Bange MP, Caton SJ & Milroy SP (2008).

Managing yields of high fruit retention in transgenic cotton (Gossypium hirsutum L.) using sowing date.

Australian Journal of Agricultural Research 59, 733-741.

Bange MP, Constable GA, Johnston DA & Kelly D (2010).

A method to estimate the effects of temperature on cotton micronaire.

Journal of Cotton Science 14, 164-172.

Bange MP, Long RL, Constable GA & Gordon SG (2010).

Minimizing immature fiber and neps in upland cotton.

Agronomy Journal 102, 781-789.

Bange MP & Long RL (2011).

Optimizing timing of chemical harvest aid application in cotton by predicting Its Influence on fiber quality.

Agronomy Journal 103, 390-395.

Baumgartner LJ, Boys CA, Stuart IG & Zampatti BP (2010).

Evaluation migratory fish behaviour and fishway performance: testing a combined assessment methodology.

Australian Journal of Zoology 58, 154-164.

Bhattarai SP & Midmore DJ (2009).

Oxygation effect on growth, gas exchange, water relation and salt tolerance of vegetable soybean and cotton in a saline vertisol.

Journal of Integrative Plant Biology 51, 675-688.

Bhattarai,SP, Midmore DJ & Pendergast L (2008).

Yield, water-use efficiencies and root distribution of soybean, chickpea and pumpkin under different subsurface drip irrigation depths and oxygation treatments in Vertisols.

Irrigation Science 26, 439-450.

Bhattarai SP, Perdergast L & Midmore DJ (2006).

Root aeration improves yield and water use efficiency of tomato in heavy clay and saline soils.

Scientia Horticulturae 108, 278-288.

Bhattari SP & Midmore DJ (2009).

Oxygation enhances growth, gas exchange and salt tolerance of vegetable soybean and cotton in a saline vertisol.

Journal of Integrative Plant Biology 51, 675-688.

Bhattarai SP, Midmore DJ & Su N (2010).

Sustainable irrigation to balance supply of soil water, oxygen, nutrients and agro-chemicals.

Sustainable Agriculture Reviews 5, 253-286.

Bhuiyan SA, Boyd MC, Dougall AJ, Martin C & Hearnden M (2007).

Effects of foliar application of potassium nitrate on suppression of alternaria leaf blight of cotton (Gossypium hirsutum) in northern Australia.

Australasian Plant Pathology 36. 462-465.

Bhuiyan SA, Boyd MC, Martin C & Hearnden M (2007).

Development of alternaria leaf blight on north Australian cotton (Gossypium hirsutum) species prevalence and its control using mancozeb.

Australasian Plant Pathology 36, 488-497.

Publications report

Bianchi F, Schellhorn NA, Buckley YM & Possingham HP (2010).

Spatial variability in ecosystem services: simple rules for predator-mediated pest suppression.

Ecological Applications 20, 2322-2333.

Bianchi FJ, Schellhorn NA & van der Werf W (2009).

Foraging behaviour of predators in heterogeneous landscapes: the role of perceptual ability and diet breadth.

Oikos 118, 1363-1372.

Bishop TFA, Nelson MA, Triantafilis J & Odeh IOA (2011).

An error budget for different sources of error in a digital soil map.

European Journal of Soil Science 62, 417–430.

Boys CA & Thoms MC (2006).

A large scale, hiererchical approach for assessing habitat associations of fish assemblages in large dryland rivers.

Hydrobiologia 572, 11-31.

Brier HB, Murray DA, Wilson LJ, Nicholas AH, Miles MM, Grundy PR & McLennan AJ (2008).

An overview of integrated pest management (IPM) in north-eastern Australian grain farming systems: past, present and future prospects.

Australian Journal of Experimental Agriculture 48, 1574-1593.

Brodrick R, Bange MP, Milroy SP & Hammer GL (2010).

Yield and maturity of ultra-narrow row cotton in high-input production systems.

Agronomy Journal 102, 843-848.

Buchanan SM & Triantafilis J (2009).

Mapping water table depth using geophysical and environmental variables.

Ground Water 46, 80-96.

Burns M, Crossan A & Kennedy I (2008).

Sorption and desorption of endosulfan sulfate and diuron to composted cotton gin trash.

Journal of Agriculture and Food Chemistry 56, 5260-5265.

Caccia S, Hernandez-Rodrigues CS, Mahon RJ, Downes S, James W, Bautsoens N, Van Rie J. & Ferre J (2010).

Binding site alteration is responsible for field-isolated resistance to Bacillus thuringiensis Cry2A insecticidal proteins in two Helicoverpa species.

Plos One, 5, no. 4.9975.

Charles GW, Constable GA, Llewellyn DJ & Hickman M (2007).

Tolerance of cotton expressing a 2,4-D detoxification gene to 2,4-D applied in the field.

Australian Journal of Agricultural Research 58 780-787.

Chen D, Freney J & Rochester I (2007).

Evaluation of a polyolefin coated urea (Meister) as fertilizer for irrigated cotton.

Nutrient Cycling in Agroecosystems 81, 245-254.

Chen D, Freney JR, Rochester, Constable GA, Mosier AR & Chalk PM (2008).

Evaluation of a polyolefin coated urea (Meister) as a fertilizer for irrigated cotton.

Nutrient Cycling in Agroecosystems 81, 245-254.

Christian P, Murray D, Powell R, Hopkinson J, Gibb N & Hanzlik T (2005).

Effective control of a field population of Helicoverpa armigera using the small RNA virus Helicoverpa armigera stunt virus (Tetraviridae: Omegatetravirus).

Journal Of Economic Entomology 98, 1839-1847.

Coleman RJ, Hereward,JP, DeBarro PJ, Frohlich DR & Goolsby JA (2008).

Molecular comparison of Creontiades plant bugs from South Texas and Australia.

Southwestern Entomologist . 33, 111-117.

Collinge DB, Jorgensen HJ, Lund OS & Lyngkjaer MF (2010).

Engineering pathogen resistance in crop plants: current trends and future prospects.

Annual Review of Phytopathology 48, 269-291.

Conaty W, Tan D, Constable G, Sutton B, Field D & Mamum E (2008).

Genetic variation for waterlogging tolerance in cotton.

Journal of Cotton Science 12, 53–61.

Constable GA, Llewellyn D, Wilson L & Stiller W (2011).

An industry transformed: the impact of GM technology on Australian cotton production.

Farm Policy Journal 8, 23-41.

Constable G, Preston C & Gupta VVSR. (2007)

The Genomic Age 3. GM cotton – benefits, risks and opportunities.

Journal of the Australian Instititute of Agriculture Science and Technology 20, 28-32.

Cottee NS, Tan DK, Bange MP, Cothren JT & Campbell LC (2010).

Multi-level determination of heat tolerance in cotton (Gossypium hirsutum L. under field conditions.

Crop Science 50, 2553-2564.

Coumans JVF, Moens PDJ, Poljak A, Al-Jaaidi S, Pereg L & Raftery MJ (2010).

Plant extract induced changes in the proteome of the soilborne pathogenic fungus Thielaviopsis basicola.

Proteomics 10, 1573-1591.

Coumans J, Harvey J, Backhouse D, Poljak A, Raftery MJ, Nehl D, Katz ME & Pereg L (2011).

Proteomics assessment of host-associated microevolution in the fungus Thielaviopsis basicola isolates. Environmental Microbiology, 13:3 576-588.

Coumans JVF, Harvey J, Backhouse D, Poljak A, Raftery MJ & Nehl D (2011).

Proteomic assessment of host-associated microevolution in the fungus Thielaviopsis basicola.

Environmental Microbiology, 13 (3): 576-588, 2011.

Datta A, Sindel BM, Kristiansen P, Birchall C, Jessop RS & Felton WL (2011).

Influence of nitrogen fertilization and isoxaflutole on the nodulation of chickpea (Cicer arietinum).

Weed Biology and Management 11, 91-99.

Del Socorro AP, Gregg PC, Alter D & Moore CJ (2010).

Development of a synthetic plant volatile-based attracticide for female noctuid moths. I. Potential sources of volatiles attractive to Helicoverpa armigera (Hubner) (Lepidoptera: Noctuidae).

Australian Journal of Entomology 49, 10-20.

Del Socorro AP, Gregg PC & Hawes AJ (2010).

Development of a synthetic plant volatile-based attracticide for female noctuid moths. III. Insecticides for adult Helicoverpa armigera (Hubner) (Lepidoptera: Noctuidae).

Australian Journal of Entomology 49, 31-39.

Dodd K, Guppy C & Lockwood P (2010).

Overcoming the confounding effects of salinity on sodic soil research.

Communications in Soil Science and Plant Analysis 41, 2211-2219.

Dodd K, Guppy C, Lockwood P & Rochester I (2010).

The effect of sodicity on cotton: Plant response to solutions containing high sodium concentrations.

Plant and Soil 330, 239–249.

Publications report

Dorahy C, Rochester I. & Blair G (2008).

Phosphorus use-efficiency by cotton grown in an alkaline soil as determined using (31) Phosphorus and (33) Phosphorus radio-isotopes.

Journal of Plant Nutrition 31, 1877-1888.

Dorahy C, Blair G & Rochester I (2007).

Availability of P from P-32-labelled endogenous soil P and P-33 labelled fertillizer in an alkaline soil producing cotton in Australia.

Soil Use and Management. 23, 192-199.

Downes S, Mahon RJ, Rossiter L, Kauter G, Leven T, Fitt G & Baker G (2010).

Adaptive management of pest resistance by Helicoverpa species (Noctuidae) in Australia to the Cry2Ab Bt toxin in Bollgard II (R) cotton.

Evolutionary Applications 3, 574-584.

Downes S, Parker T & Mahon R. (2010).

Incipient Resistance of Helicoverpa punctigera to the Cry2Ab Bt Toxin in Bollgard II (R) cotton

Plos One, 5, no. 9. e12567.

Downes S, Parker TL & Mahon RJ. (2009).

Frequency of alleles conferring resistance to the Bacillus thuringiensis toxins Cry1Ac and Cry2Ab in Australian populations of Helicoverpa punctigera (Lepidoptera: Noctuidae) from 2002 to 2006.

Journal of Economic Entomology 102, 733-742.

Downes S, Parker TL & Mahon RJ (2010).

Characteristics of resistance to Bacillus thuringiensis toxin Cry2Ab in a strain of Helicoverpa punctigera (Lepidoptera: Noctuidae) isolated from a field population.

Journal of Economic Entomology 103, 2147-2154.

Drew E, Gupta V, Roget D & Lawrence L (2006).

Herbicides and their effects on pulses in Southern Australia.

Outlooks on Pest Management 17, 166-167.

Duffield S & Dillon M (2005).

The emergence and control of overwintering Helicoverpa armigera pupae in Southern NSW.

Australian Journal of Entomology 44, 316-320.

Duggan BL, Yeates SJ, Gaff N & Constable GA (2008).

Phosphorus fertilizer requirements and nutrient uptake of irrigated dry-season cotton grown on virgin soil in tropical Australia.

Communications in Soil Science and Plant Analysis 39. 282-301.

Duggan BL, Yeates SJ & Constable GA (2005).

Bed preparation techniques and herbicide tolerance technology for tropical dry season cotton production.

Tropical Agriculture 82. 233-240.

Duggan BL, Yeates SJ, Gaff N & Constable GA (2009).

Phosphorus fertilizer requirements and nutrient uptake of irrigated dry-season cotton grown on virgin soil in tropical Australia.

Communications in Soil Science and Plant Analysis 40, 2616-2637.

Fitt GP (2009)

Opportunities for India-Australia collaboration on GM crops.

ATSE International Focus 1, pp 10-13

Fitt GP (2011).

Critical issues in pest management for a future with sustainable biofuel cropping.

Current Opinion in Environmental Sustainability 3, 71-74.

Foley JL, Tolmie PE & Silburn DM (2006).

Improved measurement of conductivity on swelling clay soils using a disc permeameter method.

Australian Journal of Soil Research 44. 701-710.

Foley DA, Rowland SJ, Wilson GG, Winters P, Nixon M & Mifsud C (2010).

New production strategy for silver perch (Bidyanus bidyanus); over-wintering fingerlings in a tank-based recirculating aquaculture system.

Aquaculture Research 41, 1574-1581.

Gamez-Virues S, Gurr GM, Raman A & Nicol HI (2010).

Plant diversity and habitat structure affect tree growth, herbivory and natural enemies in shelterbelts.

Basic and Applied Ecology 11, 542-549

Ghosh S, Hulugalle NR, Lockwood PV, King K, Kristiansen P & Daniel H (2008).

Organic amendments influence nutrient availability and cotton productivity in irrigated Vertosols. Australian.

Journal of. Agricultural. Research 59, 1068-1074.

Ghosh S, Hulugalle N, Lockwood P, Daniel H & McCorkell BE (2011).

Applying composted cotton gin trash to a Vertisol in south-eastern Queensland, Australia.

Communications in Soil Science and Plant Analysis 42, 1855-1861

Ghosh S, Lockwood P, Hulugalle N, Daniel H, Kristiansen P & Dodd K (2010).

Changes in properties of sodic Australian Vertisols with application of organic waste products.

Soil Science Society of America Journal 74, 153-160

Ghosh S, Lockwood P, Daniel H, Hulugalle N, King K & Kristiansen P (2011).

Changes in Vertisol properties as affected by organic amendments application rates.

Soil Use and Management 27, 195-204.

Ghosh, S., Lockwood, P., Daniel, H., King, K., Hulugalle N & Kristiansen P (2010).

Short-term effects of organic amendments on properties of a Vertisol.

Waste Management 28, 1087-1095.

Giambastiani BMS, McCallum AM, Andersen MS, Kelly BFJ & Acworth RI (2012):

Understanding groundwater processes by representing aquifer heterogeneity in the Maules Creek Catchment, Namoi Valley (New South Wales, Australia).

Hydrogeology Journal.

Good MK, Price JN, Clarke PJ & Reid N (2011)

Densely regenerating coolibah (Eucalyptus coolabah) woodlands are more species rich than surrounding derived grasslands in floodplains of eastern Australia.

Australian Journal of Botany 64, 468-79.

Gregg PC, Del Socorro AP & Henderson GS (2010).

Development of a synthetic plant volatile-based attracticide for female noctuid moths. II. Bioassays of synthetic plant volatiles as attractants for the adults of the cotton bollworm, Helicoverpa armigera (Hubner) (Lepidoptera: Noctuidae).

Australian Journal of Entomology 49, 21-30.

Gregg PC, Greive KA, Del Socorro AP & Hawes AJ (2010).

Research to realisation: the challenging path for novel pest management products in Australia.

Australian Journal of Entomology 49, 1-9.

Greve AK, Acworth IR & Kelly BF (2010).

Detection of subsurface soil cracks by vertical anisotropy profiles of apparent electrical resistivity.

Geophysics 75, 85-93.

Publications report

Greve A, Andersen MS & Acworth RI (2010).

Investigations of soil cracking and preferential flow in a weighing lysimeter filled with cracking clay soil.

Journal of Hydrology 393, 105-113.

Greve AK, Acworth RI & Kelly BFJ (2011).

3d cross-hole resistivity tomography to monitor water percolation during irrigation on cracking soil.

Soil Research 49, 661-69.

Gu HN, Fitt GP & Baker GH (2007).

Invertebrate pests of canola and their management in Australia- a review.

Australian Journal of Entomology 46, 231-243.

Gunawardena TA, McGarry D, Robinson JB & Silburn DM (2011).

Deep drainage through Vertosols in irrigated fields measured with drainage lysimeters.

Soil Research 49, 343-354.

Gurr GM, Horne P, Page J, Ash GJ & Pilkington LJ (2010).

Australia and New Zealand Biocontrol Conference: Emerging Themes, Future Prospects.

Biological Control 52, 195-197.

Gurr GM & Kvedaras OL. (2010).

Synergizing biological control: scope for sterile insect technique, induced plant defences and cultural techniques to enhance natural enemy impact.

Biological Control. 52, 198-207.

Hendry AP, Kinnison MT, Heino M, Day T, Smith TB, Fitt G, Bergstrom CT, Oakeshott J, Jorgensen PS, Zalucki MP, Gilchrist G, Southerton S, Sih A, Strauss S, Denison RF & Carroll SP (2011).

Evolutionary principles and their practical application.

Evolutionary Applications 4, 159-183.

Herron N & Croke B (2009).

Including the influence of groundwater exchanges in a lumped rainfall-runoff model.

Mathematics and Computers in Simulation, 79, 2689-2700.

Herron GA & Wilson LJ (2011)

Neonicotinoid resistance in Aphis gossypii Glover (Aphididae: Hemiptera) from Australian cotton.

Australian Journal of Entomology 50, 93-98.

Hulugalle NR (2005).

Recovering leached N by sowing wheat after irrigated cotton in a Vertisol.

Sustainable Agriculture 27, 39-51.

Hulugalle NR, McCorkell BE, Weaver TB & Findlay LA (2010).

Managing sodicity and exchangeable K in a dryland Vertisol in Australia with deep tillage, cattle manure, and gypsum.

Arid Land Research and Management 24, 181-195.

Hulugalle NR, McCorkell BE, Weaver TB, Finlay LA & Gleeson J (2007).

Soil properties in furrows of an irrigated Vertisol sown with continuous cotton (Gossypium hirsutum L.).

Soil and Tillage Research, 97, 162-171.

Hulugalle NR & Scott F (2008).

A review of the changes in soil quality and profitability accomplished by sowing rotation crops after cotton in Australian Vertosols from 1970 to 2006.

Australian Journal of Soil Research, 46, 173-190.

Hulugalle NR, Weaver TB & Finlay LA. (2010).

Carbon inputs by irrigated corn roots to a Vertisol.

Plant Root 4, 18-21.

Hulugalle NR & Weaver TB (2005).

Short term variations in chemical properties of vertisols as affected by amounts, carbon/nitrogen ratio, and nutrient concentration of crop residues.

Communications in Soil Science and Plant Analysis 36, 1449-1464.

Hulugalle NR, Weaver TB & Findlay LA (2010).

Soil water storage and drainage under cotton-based cropping systems in a furrow-irrigated Vertisol.

Agricultural Water Management 97, 1703-U3.

Hulugalle NR, Weaver TB & Finlay LA (2006).

Residual effects of cotton-based crop rotations on soil properties of irrigated Vertisols in central-western and north-western NSW.

Australian Journal of Soil Research 44, 467-477.

Hululgalle NR, Weaver TB & Scott F (2005).

Continuous cotton and a cotton-wheat rotation effects on soil properties and profitability in an irrigated Vertisol.

Journal of Sustainable Agriculture 27, 5-24.

Hulugalle NR, Finlay LA & Weaver TB (2011).

An integrated mechanical and chemical method for managing prostrate cover crops on permanent beds.

Renewable Agriculture and Food Systems.

Ives AR & Schellhorn NA (2011).

Novel pests and technologies: risk assessment in agroecosystems using simple models in the face of uncertainties.

Current Opinion in Environmental Sustainability 3, 100-104.

Jenkins K, Kingsford R & Ryder D (2009).

Developing indicators for floodplain wetlands: Managing water in agricultural landscapes.

Chiang Mai Journal of Science 36, 224-235.

Jonsson M, Wratten SD, Landis DA & Gurr GM (2008).

Recent Advances in conservation biological control or arthropods by arthropods.

Biological Control 45, 172-175.

Kelleway J, Mazumder D, Wilson GG, Saintilan N, Knowles L & Kobayashi T (2010).

Variation in the trophic structure of benthic resources, crustaceans and fish across a floodplain river wetland.

Marine and Freshwater Research 61, 430–440

Kelleway J, Mazumder D, Wilson GG, Saintilan N, Knowles L, Iles J & Kobayashi T (2010).

Trophic structure of benthic resources and consumers varies across a regulated floodplain wetland.

Marine and Freshwater Research 61, 430-440.

Kelly BFJ, Acworth RI & Greve AK (2011).

Better placement of soil moisture point measurements guided by 2D resistivity tomography for improved irrigation scheduling.

Soil Research 49, 504-512.

Kelly B, Allen D, Ye K & Dahlin T (2009).

Continuous electrical imaging for mapping aquifer recharge along reaches of the Namoi River in Australia.

Near Surface Geophysics 7, 259-270.

Khan M, Gregg P & Mensah R (2009).

Effect of temperature on the biology of Creontiades dilutus (Stal) (Heteroptera: Miridae).

Australian Journal of Entomology 48, 210-216.

Knight KM & Gurr GM (2007).

Review of Nezara viridula (L.) management strategies and potential for IPM in field crops with emphasis on Australia.

Crop Protection 26, 1-10.

Publications report

Knox OGG, Walker RL, Booth EJ, Hall C, Crossan A & Gupta VVSR (2011)

Capitalising on deliberate, accidental and GM driven environmental change caused by crop modification.

Journal of Experimental Botany. 63: 543-549

Knox OK, Gupta VVSR & Lardner R (2009)

Cotton cultivar selection impacts on microbial diversity and function.

Aspects of Applied Biology (Positive Plant Microbial Interactions in relation to Plant Performance and Ecosystem Function, 98, 129-136.

Knox OGG, Gupta VVSR, Roberts GN & Downes SJ (2008)

Improving environmental loading assessments of Cry protein from GM plants based on experimentation in cotton.

The Open Agriculture Journal. 2, 105-112

Knox OGG, Nehl DB, Mor T, Roberts GN & Gupta VVSR (2008)

Genetically modified cotton has no effect on arbuscular mycorrhizal colonization of roots.

Field Crops Research. 109: 57-60

Knox OCG, Gupta VVSR, Nehl DB & Stiller WN (2007)

Constitutive expression of Cry proteins in roots and border cells of transgenic cotton.

Euphytica. 154, 83-90

Knox OGG, Anderson CMT, Nehl DB, Gupta VVSR (2006)

Observation of Tylenchorhynchus ewingi in association with cotton soils in Australia.

Australasian Plant Disease Notes. 2006 (1), 47-48

Knox OG, Anderson CM, Allen SJ & Nehl DB (2006).

Helicotylenchus dihystera in Australian cotton roots.

Australasian Plant Pathology 35, 287-288.

Knox OG, Constable GA, Pyke B & Gupta VS (2006).

Environmental impact of conventional and Bt insecticidal cotton expressing one and two Cry genes in Australia.

Australian Journal of Agricultural Research 57, 501-509.

Korbel KL & Hose GC (2011).

A tiered framework for assessing groundwater ecosystem health.

Hydrobiologia 661, 329-349.

Kvedaras O, Del Socorro AP & Gregg, PC (2007).

Effects of phenylacetaldehyde and (Z)-3-hexenyl acetate on male response to synthetic sex pheromone in Helicoverpa armigera (Hubner) (Lepidoptera:Noctuidae).

AustralianJjournal of Entomology 46, 224-230.

Lategan MJ, Korbel K & Hose GC (2010).

Is cotton-strip tensile strength a surrogate for microbial activity in groundwater?

Marine and Freshwater Research 61, . 351-356.

Lavandero B, Wratten SD, Didham RH & Gurr GM (2006).

Increasing floral diversity for selective enhancement of biological control agents: a double edged sward? B

asic and Applied Ecology 7, 236-243.

Lawrence L, Tann C & Baker G (2007).

Refuge crops for Helicoverpa in Australian cotton farming systems.

Outlook on Pest Management 18, 19-20.

Lee LYT, Ancev T & Vervoort RW (2007)

Environmental and economic impacts of water scarcity and market reform on the Mooki catchment.

The Environmentalist 27, 39-49.

Lee Y & Ancev T (2009).
Two Decades of Murray-Darling water management: a river of funding, a trickle of achievement.
Agenda- A Journal of Policy Analysis & Reform 16, 5-23.

Liu SS, De Barro PJ, Xu J, Luan JB, Zang LS, Ruan YM & Wan FH (2007).
Asymmetric Mating interactions drive widespread invasion and displacement in a whitefly.
Science 318, 1769-1772.

Long RL &Bange MP (2011).
Consequences of immature fiber on the processing performance of Upland cotton.
Field Crops Research 121, 401-407.

Long RL, Bange MP, Gordon SG & Constable GA (2010).
Measuring the maturity of developing cotton fibers using an automated polarized light microscopy technique.
Textile Research Journal 80, 463-471.

Long RL, Bange MP, Gordon SG, Van Der Sluijs MH, Naylor GR & Constable GA (2010).
Fiber quality and textile performance of some Australian cotton genotypes.
Crop Science 50, 1509-1518.

Long RL, Walsh KB, Midmore DJ & Rogers G (2006).
Irrigation scheduling to increase muskmelon fruit biomass and soluble solids concentration.
Hortscience 41. 367-369.

Lowor S, Del Socorro A & Gregg P (2009).
A sex attractant of the rough bollworm, Earias huegeliana (Gaede) (Lepidoptera: Noctuidae).
Scientific Research and Essays 4, 419-425.

Lowor ST, Del Socorro AP & Gregg PC (2009).
Sex pheromones of the green mirid, Creontiades dilutus (Stal) (Hemiptera: Miridae).
International Journal of Agriculture Research 4, 137-145.

Lowor ST, Gregg PC & Del Socorro AP (2010).
Potential for pheromone based attract-and-kill and mating disruption of the green mirid, Creontiades dilutus (Stal) (Hemiptera:Miridae).
International Journal of Agricultural Research 4, 153-162.

Lu BQ, Downes S, Wilson L, Gregg P, Knight K, Kauter G & McCorkell B (2011.
Preferences of field bollworm larvae for cotton plant structures: impact of Bt and history of survival on Bt crops.
Entomologia Experimentalis et Applicata 140, 17-27.

Lutton SJ, Sheldon F & Bunn SE (2009).
Morphological characteristics of on-farm water storages and their similarity to natural water bodies in the Border Rivers Catchment, Australia.
Aquatic Conservation: Marine and Freshwater Ecosystems 20, 47-57.

McColl S, Khan M & Umina P (2011).
Review of the biology and control of Creontiades dilutus (Stål) (Hemiptera: Miridae).
Australian Journal of Entomology 50, 107-117.

Mahan JR, Conaty W, Neilsen J, Payton P & Cox SB (2010).
Field performance in agriculture settings of a wireless temperature monitoring system based on a low-cost infrared sensor.
Computers and Electronics in Agriculture, 71 176-181.

Publications report

Mahon RJ, Downes S, James W & Parker T (2010).

Why do F-1 Screens Estimate Higher Frequencies of Cry2Ab Resistance in Helicoverpa armigera (Lepidoptera: Noctuidae) Than Do F-2 Screens?.

Journal of Economic Entomology 103, 472-481.

Manandhar R, Odeh IOA & Ancev T (2009).

Improving the accuracy of land use and land cover classification of Landsat data using post-classification enhancement.

Remote Sensing 1(3):330-344.

Mansfield S, Dillon M & Whitehouse M (2006).

The impact of season-long insecticide regimes on beneficial arthropod communities in Australian cotton fields.

Agriculture, Ecosystems and Environment 113, 326-335.

Mansfield S, Dillon ML & Whitehouse M (2006).

Are arthropod communities in cotton really disrupted? An assessment of insecticide regimes and evaluation of the beneficial disruption index.

Agriculture, Ecosystems and Environment 113, 326-335.

Mansfield S, Hagler SR & Whitehouse ME (2008).

A comparative study of the efficiency of a pest-specific and prey-marking ELISA for detection of predation.

Entomologia Experimentalis et Applicata 127, 199-206.

McCallum AM, Andersen MS, Giambastiani BMS, Kelly BFJ & Acworth RI (2012)

River-aquifer interaction in a semi-arid environment stressed by groundwater abstraction. Hydrologic Processes.

McDowell AJ, Bange MP & Tan DK (2007).

Cold temperature exposure at 10c for 10 and 20 nights does not reduce tissue viability in vegetative and early flowering cotton plants.

Australian Journal of Experimental Agriculture 47, 198-207.

McHugh AD, Bhattarai S, Lotz G & Midmore DJ (2008).

Effects of subsurface drip irrigation rates and furrow irrigation for cotton grown on a vertisol on off-site movement of sediments, nutrients and pesticides.

Agronomy for Sustainable Development 28, 507-519.

McHugh AD, Bhattarai SB, Lotz G & Midmore DJ (2008).

Soil erosion and off-site movement of nutrients and pesticides from furrow and subsurface drip irrigated cotton on a vertisol.

Agronomy for Sustainable Development 28, 507-519.

Mensah RK, Vodouhe DS, Assogba G & Monday P (2012)

Increasing organic cotton production in Benin West Africa through a supplementary food spray product to manage pests and beneficial insects.

International Journal of Pest Management 58, 53 - 64.

Mensah RK, Austin L & Anderson S (2012).

Microbial control of cotton pests Part I: Development and use of Entomopathogenic fungus Aspergillus s (BC 639) in the management of Creontiades dilutus (Stal) (Hemiptera : Miridae) and beneficial insects on transgenic cotton crops.

Journal of Biocontrol Science & Technology

Mensah RK & Moore C (2011).

Exploitation of semiochemicals for insect pest management with special emphasis on cotton: A Review.

Journal of Biological Control 25, 253 - 264

Mensah RK & Macpherson I (2010).

Lure-and-kill as reduced-risk strategy for managing Helicoverpa s on conventional cotton crops within transgenic cotton fields.

Journal of Biocontrol 24, 91-103.

Mensah RK, Frerot B & Al Dabel F (2005).
Effects of Petroleum Spray oils on oviposition behaviour and larval survival of Helicoverpa armigera (Lepidoptera: Noctuidae) and Ostrinia nubilalis (Lepidoptera:Pyralidae).
International Journal of Pest Management 51, 111-119.

Mensah RK, Liang W, Gibb D, Coates R & Johnson D (2005).
Evaluation of nC27 Petroleum spray oil for activity against Helicoverpa s on commercial cotton fields in Australia.
International Journal of Pest Management 51, 63-70.

Midgley DJ, Saleeba JA, Stewart MI & McGee PA (2007).
Novel soil lineages of Archaea are present in semi-arid soils of eastern Australia.
Canadian Journal of Botany 53, 129-138.

Midgley DJ, Saleeba JA, Stewart MI, Simpson AE & McGee PA (2007).
Molecular diversity of soil basidiomycete communities in northern-central New South Wales, Australia.
Mycological Research 111, 370-378.

Milroy SP, Bange MP & Thongbai P (2009).
Cotton leaf nutrient concentrations in response to waterlogging under field conditions.
Field Crops Research 113, 246-255.

Minasny B & Field DJ (2006).
Estimating soil hydraulic properties and their uncertainty: use of stochastic simulation in the inverse modeling of the evaporation method.
Geoderma 126, 277-290.

Minasny B, McBratney AB, Mendonça-Santos ML, Odeh IOA & Guyon B (2006).
Prediction and digital mapping of soil carbon storage in the Lower Namoi Valley.
Australian Journal of Soil Research 44: 233-244.

Monteiro Santos FA, Triantafilis J, Bruzgulis KE & Roe JAE (2010).
Inversion of DUALEM-421 profiling data using a 1-D laterally constrained algorithm.
Vadose Zone Journal 9, 117-125.

Monteiro Santos FA, Triantafilis J, Taylor R, Holladay S & Bruzgulis KE (2010).
Inversion of conductivity profiles from EM using full solution and a 1-D laterally constrained algorithm.
Journal of Engineering and Environmental Geophysics 15, 163-174.

Monteiro Santos FA, Triantafilis J & Bruzgulis KE (2011).
A spatially constrained 1-d inversion algorithm for quasi-3D conductivity imaging: Application to DUALEM421 data collected in a riverine plain.
Geophysics 76, B43-B53.

Najar-Rodriguez AJ Walter GH & Mensah RK (2007).
The efficacy of a petroleum spray oil against Aphis gossypii Glover on cotton Part 1: Morality rates and source of variation.
Pest Management Science 63, 586-595.

Najar-Rodriguez AJ, Walter GH & Mensah RK (2007).
The efficacy of a petroleum spray oil against Aphis gossypii Glover on cotton Part 2: Indirect effect of oil deposits.
Pest Management Science 63, 596-607.

Najar-Rodriguez AJ, Lavidis NA , Mensah RK, Choy, PT and Walter GH. (2008).
The toxicological effects of petroleum spray oils on insects - evidence for an alternative mode of action and possible new control options.
Food and Chemical Toxicology 46, 3003-3014.

Publications report

Najar-Rodriguez AJ, McGraw EA, Mensah RK, Pittman GW & Walter GH (2009)

The microbial flora of Aphis gossypii: Patterns across host plants and geographical space.

Journal of Invertebrate Pathology, 100, 123-126.

Najar-Rodriguez, A.J, McGraw EA, Hull CD, Mensah RK & Walter GH. (2009).

The ecological differentiation of asexual lineages of cotton aphids: Alate behaviour, sensory physiology and differential host associations.

Biological Journal of the Linnean Society. 97, 503-519.

Nehl DB & Knox OG (2006).

Significance of bacteria in the rhizosphere.

Microbial Activity in the Rhizosphere 7, 89-119.

Nelson MA & Odeh IO (2009).

Digital soil class mapping using legacy soil profile data: A comparison of a genetic algorithm and classification tree approach.

Australian Journal of Soil Research 47, 632-649.

Nelson MA, Bishop TFA, Odeh IOA & Triantafilis J (2011).

An error budget for deferent sources of error in digital soil mapping.

European Journal of Soil Science, 62, 417-430.

Odeh IOA & Onus A (2008).

Spatial analysis of soil salinity and sodicity in an irrigated semiarid region of New South Wales, Australia.

Environmental Management 42: 265-278.

Odeh IOA & Tan D (2007).

Expanding biofuel production in Australia: opportunities beyond the horizon.

Farm Policy Journal 4, 29-39.

Olsen K, Daly J, Finnegan E. & Mahon R (2005).

Changed in Cry1Ac Bt transgenic cotton in response to two environmental factors: temperature and insect damage.

Journal of Economic Entomology 98, 1382-1390.

Osten VA, Walker SR & Storrier A (2007).

Survey of weed flora and management relative to cropping practices in the north-eastern grain region of Australia.

Australian Journal of Experimental Agriculture, 47, 57-70.

Payero JO, Tarkalson DD, Irmak S, Davison S & Peterson JL (2009).

Effect of timing of a deficit-irrigation allocation on corn evapotranspiration, yield, water use efficiency and dry mass.

Agricultural Water Management 96, 1387-1397.

Peoples MB, Brockwell J, Herridge DF, Rochester IJ, Alves BJ, Urquiaga S, Boddey RM, Dakora FD, Bhattarai S, Maskey SL, Sampet C, Rerkasem B, Kahn DF, Hauggaard-Nielsen H & Jensen ES (2009).

The contributions of nitrogen-fixing crop legumes to the productivity of agricultural systems.

Symbiosis (Rehovot) 48, 1-17.

Quilty JR & Cattle SR (2011).

Use and understanding of organic amendments in Australian agriculture: a review.

Soil Research 49, 1-26.

Radford B, Yule D & McGarry D (2007).

Amelioration of soil compaction can take 5 years on a Vertisol under no till in the semi-arid subtropics.

Soil and Tillage Research 97, 249-255.

Rahat S, Gurr GM, Campbell G, Wratten SD, Mo J & Neeson R (2005).

Effect of plant nectars on longevity of the stinkbug parasitoid, Trissolcus basalis.

International Journal of Pest Management 51, 321-324.

Rau GC, Andersen MS, McCallum AM & Acworth RI (2010).

Analytical methods that use natural heat as a tracer to quantify surface water-groundwater exchange, evaluated using field temperature records.

Hydrogeology Journal 18, 1093-1110.

Reddall AA, Wilson L, Gregg PC & Sadras VO (2007).

Photosynthetic response of cotton to spider mite damage: interaction with light and compensatory mechanisms.

Crop Science 47, 2047-2057.

Reddall AA, Sadras VO, Wilson LJ & Gregg PC (2011).

Contradictions in host plant resistance to pests: spider mite (Tetranychus urticae Koch) behaviour undermines the potential resistance of smooth-leaved cotton (Gossypium hirsutum L.).

Pest Management Science 67, 360-369.

Richards JS , Stanley JN & Gregg PC (2005)

Viability of cotton and canola pollen on the proboscis of Helicoverpa armigera: implications for spread of transgenes and pollination ecology.

Ecological Entomology 30, 327-333.

Ridley AW, Hereward JP, Daglish GJ, Raghu S, Collins PJ, & Walter GH (2011).

The spatiotemporal dynamics of Tribolium castaneum (Herbst): adult flight and gene flow.

Molecular Ecology 20, 1635-1646.

Richards QD, Bange MP & Johnston SB (2008).

HydroLOGIC: An irrigation management system for Australian cotton.

Agricultural Systems 98, 40-49.

Robinson JB, Silburn DM, Rattray D, Freebairn DM, Biggs A, McClymont D & Christodoulou N (2010).

Modelling shows that the high rates of deep drainage in parts of the cotton.

Nutrient Cycling in Agroecosystems 90, 147-156.

Rochester IJ (2006).

Effect of genotype, edaphic, environmental conditions and agronomic practices on Cry1Ac protein expression in transgenic cotton.

Journal of Cotton Science 10. 252-262.

Rochester IJ (2007).

Nutrient uptake and export from an Australian cotton field.

Nutrient Cycling in Agroecosystems 77, 213-223.

Rochester IJ (2010).

Assessing internal crop Nitrogen use efficiency in high-yielding irrigated cotton.

Nutrient Cycling in Agroecosystems 81, 245-254.

Rochester I.J (2010).

Phosphorus and Potassium nutrition of cotton: interaction with sodium.

Crop and Pasture Science 61, 825-834.

Rochester IJ (2011).

Sequestering carbon in minimum-tilled clay soils used for irrigated cotton and grain production.

Soil & Tillage Research 112, 1-7.

Rochester IJ & Peoples MB (2005).

Growing vetches in irrigated cotton systems: inputs or fixed N, N fertiliser savings and cotton productivity.

Plant and Soil 271, 251-264.

Rochester IJ (2012).

Using seed nitrogen concentration to estimate crop N use efficiency in high-yielding irrigated cotton.

Field Crops Research 127, 140-145.

Publications report

Rolls RJ & Wilson GG (2010).
Spatial and temporal patterns in fish assemblages following an artificially extended floodplain inundation event, Northern Murray-Darling Basin, Australia.
Environmental Management 45, 822-833.

Rose MT, Crossan AN & Kennedy IR (2007).
Dissipation of cotton pesticides from runoff water in glasshouse columns.
Water, Air, & Soil Pollution 182, 207-218.

Rose MT, Crossan AN & Kennedy IR (2008).
The effect of vegetation on pesticide dissipation from ponded treatment wetlands: Quantification using a simple model.
Chemosphere 72, 999-1005.

Rose MT, Sanchez-Bayo F, Crossan AN & Kennedy IR (2006).
Pesticide removal from cotton farm tailwater by a pilot-scale ponded wetland.
Chemosphere 63, 1849-1858.

Rose MT, Deaker R, Potard S, Cuc KTT, Vu NT & Kennedy IR (2011).
The survival of plant growth promoting microorganisms in peat inoculant as measured by selective plate counting and enzyme-linked immunoassay.
World Journal of Microbiology & Biotechnology 27, 1649-1659.

Rossel RAV, Jeon YS, Odeh IOA & McBratney AB (2008).
Using a legacy soil sample to develop a mid-IR spectral library.
Australian Journal of Soil Research 46, 1-16.

Rowland SJ (2009)
Review of aquaculture research and development of the Australian freshwater fish silver perch, Bidyanus bidyanus.
Journal of the World Aquaculture Society, 40, 291-324.

Ryder DS, Tomilson M, Gawne B & Likens GE (2010).
Defining and using 'best available science': a policy conundrum for the management of aquatic ecosystems.
Marine and Freshwater Research 61, 821-828.

Schellhorn N, Bellati J & Paull C (2008).
Parastioid and moth movement from refuge to crop.
Basic and Applied Ecology 9, 691-700.

Schellhorn N & Lawrence L (2008).
The role of landscape in area wide management of silverleaf whitefly.
Outlooks on Pest Management 19, 171-172.

Schellhorn NA, Glatz RV & Wood GM (2010).
The risk of exotic and native plants as hosts for four pest thrips (Thysanoptera: Thripinae).
Bulletin of Entomological Research 100, 501-510.

Schellhorn NA, Pearce S, Bianchi FJ, Williams DG & Zalucki M (2008).
Managing ecosystem services in broad-acre landscapes: what are the appropriate spatial scales?
Australian Journal of Experimental Agriculture, 48, 1549-1559.

Scott KD, Lange CL, Scott LJ & Graham GC (2006).
Isolation and characterisation of microsatellite loci from Helicoverpa armigera Hubner.
Molecular Ecology Notes 4, 204-205.

Scott KD, Lawrence N, Lange CL, Scott LJ, Wilkinson KS, Merritt MA, Miles M, Murray D & Graham GC (2006).
Assessing moth migration and population structuring in the cotton bollworm Helicoverpa armigera Hubner at the regional scale: Example from the Darling Downs, Australia.
Journal of Entomology 98, 2210-2219.

Scott KD, Wilkinson KS, Lawrence N, Lange CL, Scott LJ, Merritt MA, Lowe AJ & Graham GC (2006).
Gene-flow between populations of cotton bollworm Helicoverpa armigera Hubner is highly variable between years.
Bulletin of Entomology Research 95, 381-392.

Scott KD, Wilkinson KS, Merritt MA, Scott LJ, Lange CL, Schutz MK, Kent KJ, Merritt DJ, Grundy PR & Graham GC (2006).
Genetic shifts in Helicoverpa armigera over a year in the Dawson/Callide Valleys.
Australian Journal of Agricultural Research 54, 739-744.

Scott, L.J, Lawrence N., Lange CL, Graham GC, Hardwick S, Rossiter L, Dillon ML & Scott KD (2006).
Population dynamics and gene flow of Helicoverpa armigera on cotton and grain crops in the Murrumbidgee Valley, Australia.
Journal of Economic Entomology 99, 115-163.

Sequeira RV & Naranjo SE (2008).
Sampling and management of Bemisia tabaci (Genn.(biotype B) in Australian cotton.
Crop Protection 27, 1262-1268.

Sequeira RV, Shields A, Moore A.& De Barro P (2009).
Inter-Seasonal population of dynamics and pest status of Bemisia tabaci (Gennadius) biotype B in an Australian cropping system.
Bulletin of Entomological Research 99, 325-335.

Silburn DM & Hunter HM (2009).
Management practices for control of runoff losses from cotton furrows under storm rainfall. III. Cover and wheel traffic effects on nutrients (N and P) in runoff from a black Vertosol.
Australian Journal of Soil Research 47, 221-233.

Silburn DM (2011).
Hillslope runoff and erosion on duplex soils in grazing lands in semi-arid central Queensland. II. Simple models for suspended and bedload sediment.
Soil Research 49, 118-126.

Silburn DM, Tolmie PE, Biggs AJW, Whish JPM & French V (2011).
Deep drainage rates of Grey Vertosols depend on land use in semi-arid subtropical regions of Queensland, Australia.
Soil Research 49, 424-438.

Stiller W, Read J, Constable G & Reid, P (2005).
Selection for water use efficiency traits in a cotton breeding program: Cultivar differences.
Crop Science 45 1107-1113.

Tennakoon SB & Hulugalle NR (2006).
Impact of crop rotation and minimum tillage on water use efficiency of irrigated cotton in a Vertisol.
Irrigation Science 25, 45-52.

Thornby D & Walker S (2009).
Simulating and investigating glyphosate resistance evolution in the northern Australian grains region.
Annals of Botany 104, 747-756.

Publications report

Thrall PH, Oakeshott JG, Fitt G, Southerton S, Burdon JJ, Sheppard A, Russell RJ, Zalucki M, Heino M & Denison RF (2011).

Evolution in agriculture: the application of evolutionary approaches to the management of biotic interactions in agro-ecosystems.

Evolutionary Applications 4, 200-215.

Timms WA & Acworth RI (2005).

Propagation of pressure change through thick clay sequences: An example from Liverpool Plaines NSW Australia.

Hydrogeology Journal 13, 858-870.

Tolmie PE, Silburn DM, Biggs AJW (2011).

Deep drainage and soil salt loads in the Queensland Murray-Darling Basin using soil chloride: comparison of land uses.

Soil Research 49, 408-423.

Triantafilis J & Lesch SM (2005).

Mapping clay content variation using electromagnetic induction techniques.

Computers and Electronics in Agriculture 46, 203-237.

Triantafilis J & Monteiro Santos FA (2009).

2-dimensional soil and vadose zone representation using an EM38 and EM34 and a laterally constrained inversion model.

Australian Journal of Soil Research 47, 809-820.

Triantafilis J, Lesch SM, Lau KL & Buchanan SM (2009).

Field level digital soil mapping of cation exchange capacity using electromagnetic induction and a hierarchical spatial regression model.

Australian Journal of Soil Research 47, 651-663.

Triantafilis J, Kerridge B & Buchanan SM (2009).

Digital soil-class mapping from proximal and remotely sensed data at the field level.

Agronomy Journal 101, 841-853.

Triantafilis J & Buchanan SM (2009).

Identifying common near-surface and subsurface stratigraphic units using EM34 signal data and fuzzy k-means analysis in the Darling River valley.

Australian Journal of Earth Sciences 56, 535-556.

Triantafilis J & Monteiro Santos FA (2010).

Resolving the spatial distribution of the true electrical conductivity with depth using EM38 and EM31 signal data and a laterally constrained inversion model.

Australian Journal of Soil Research 48, 434-446.

Triantafilis J & Buchanan SM (2010)

Mapping the spatial distribution of saline sub-surface material in the Darling River valley.

Journal of Applied Geophysics 70, 144-160.

Triantafilis J & Monteiro Santos FA (2011).

Hydrostratigraphic analysis of the Darling River valley using a joint inversion of EM38 and EM34 data and a 1D spatially constrained algorithm for quasi-3D conductivity imaging.

Hydrogeology Journal 19, 1053-1063.

Vandermeer J, Perfecto I & Schellhorn N (2010).

Propagating sinks, ephemeral sources and percolating mosaics: conversation in landscapes.

Landscape Ecology 25, 509-518.

van Ogtrop F, Vervoort R, Heller G, Stasinopoulos D & Rigby R (2011)

Long-range forecasting of intermittent streamflow.

Hydrology and Earth System Sciences 15: 3343-3354.

Vervoort RW & Annen Y (2006).
Palaechannels in northern NSW: Inversion of electromagnetic induction data to infer hydrologically relevant stratigraphy.
Australian Journal of Soil Research 44, 35-45.

Vervoort RW, Minasny B & Cattle SR (2006).
The hydrology of Vertisols used for cotton production: II. Pedotransfer functions to predict hydraulic properties.
Australian Journal of Soil Research 44, 479-486.

Vodouuhe DS, Mensah R, Sanfilippo D & Assogba G (2009).
A new tool for improving organic cotton yields in Africa.
Pesticides News, 84, 6-9.

Wade MR, Gurr GM & Wratten SD (2008).
Ecological restoration in farmland. Philosophical Transactions of the Royal Society, Series B- Biological Sciences.
Special Issue: Sustainable Agriculture 323. 831-847.

Walker S, Wu H & Bell K (2010).
Emergence and persistence of Echinochloa colona, Urochloa panicoides and Hibiscus trionum in the sub-tropical environment of north-east Australia.
Plant Protection Quarterly 25, 127-132.

Walker SR, Taylor IN & Milne G (2005).
A survey of management and economic impact of weeds in dryland cotton cropping systems of subtropical Australia.
Australian Journal of Experimental Agriculture 45, 79-91.

Wang XJ, Lester DW, Guppy CN, Lockwood PV & Tang C (2007).
Changes in phosphorus fractions at various soil depths following long-term P fertilizer application on a Black Vertosol from southeastern Queensland.
Australian Journal of Soil Research 45, 524-532.

Wang X, Tang C, Guppy CN & Sale PW (2008).
Phosphorus acquisition characteristics of cotton (Gossypium hirsutum), wheat (Triticum aestivum L.) and white lupin (Lupinus albus) under P deficient conditions.
Plant and Soil 312, 117-128.

Wang X, Tang C, Guppy CN & Sale PW (2009).
The role of hydraulic lift and subsoil P placement on P uptake of cotton (Gossypium hirsutum L.).
Plant and Soil 325, 263-275.

Wang XJ, Tang CX, Guppy CN & Sale PW (2010).
Cotton, wheat and white lupin differ in phosphorus acquisition from sparingly soluble sources.
Environmental and Experimental Botany 69, 267-272.

Wang X, Guppy CN, Watson L, Sale PWG & Tang C (2011).
Availability of sparingly soluble phosphorus sources to cotton (Gossypium hirsutum L.), wheat (Triticum aestivum L.) and white lupin (Lupinus albus L.) with different forms of nitrogen as evaluated by a 32P isotopic dilution technique.
Plant and Soil 348:85-98.

Ward AL (2006).
Development of a treatment threshold for sucking insects in determinate Bollgard II transgenic cotton grown in winter production areas.
Australian Journal of Entomology 44, 310-315.

Watts RJ, Ryder DS, Allan C & Commens S (2010).
Using river-scale experiments to inform variable releases from large dams: A case study of emergent adaptive management.
Marine and Freshwater Research 61, 786-797.

Weaver TB, Hulugalle NR & Ghadiri H (2005).
Comparing deep drainage estimated with transient and steady state assumptions in irrigated Vertisols.
Irrigation Science 24, 183-191.

Publications report

Werth J, Preston C, Roberts G & Taylor I (2008).
Weed management impacts on the populations dynamics of Echinochloa crus-galli in glyphoste resistant cotton.
Weed Technology 22, 190-194.

Werth J, Walker S, Boucher L & Robinson G (2010).
Applying the double knock technique to control Conyza bonariensis.
Weed Biology and Management 10, 1-8.

Werth JA, Preston C, Roberts GN & Taylor IN (2006).
Weed management practices in glyphosate tolerant and conventional cotton fields in Australia.
Australian Journal of Experimental Agriculture n46, 1177-1183

Werth JA, Preston C, Taylor IN, Charles GW, Roberts GN & Baker J (2007).
Managing the risk of glyphosate resistance in Australian glyphosate-resistant cotton production systems.
Pest Management Science 64, 417-421

Werth J, Thornby D, Walker S (2011)
Assessing weeds at risk of evolving glyphosate resistance in Australian sub-tropical glyphosate-resistant cotton systems.
Crop & Pasture Science 62, 1002-1009.

Whiffen LK, Midgley DJ & McGee PA (2006).
Polyphenolic compounds interfere with quantification of protein in soil extracts using the Bradford method.
Soil Biology & Biochemistry 39, 691-694.

Whitehouse ME (2009).
Evidence of a latitudinal gradient in spider diversity in Australian cotton
Austral Ecology 34, 10-23.

Whitehouse ME, Fitt GP & Wilson LJ (2006).
A comparison of arthropod communities in transgenic Bt and conventional cotton Australia.
Environmental Entomology 34, 1224-1241.

Whitehouse ME & Grimshaw J (2007).
Distinguishing between Lynx spiders (Oxyopidae) relevant to IPM in Namoi Valley cotton.
The Australian Entomologist 34, . 97-106.

Whitehouse ME, Hardwick S, Scholz BC, Annells A, Ward A, Grundy P & Harden S (2009).
Evidence of latitudinal gradient in spider diversity in Australian cotton.
Austral Ecology 34, 10-23.

Whitehouse ME, Wilson LJ & Constable G (2007).
Target and non-target effects on the invertebrate community of Vip cotton, a new insecticidal transgenic.
Australian Journal of Agricultural Research 58, 273-285.

Whitehouse MEA (2011).
IPM of mirids in Australian cotton: Why and when pest managers spray for mirids.
Agricultural Systems 104, 30-41.

Whitehouse MEA, Mansfield S, Barnett MC & Broughton K (2011).
From lynx spiders to cotton: Behaviourally mediated predator effects over four trophic levels.
Austral Ecology 36, 687-697.

Widderick MJ, Walker SR, Sindel BM & Bell KL (2010).
Germination, emergence, and persistence of Sonchus oleraceus, a major crop weed in subtropical Australia.
Weed Biology and Management 10, 102-112.

Wilson LJ, Lei TT, Sadras VO, Wilson LT and Heimoana SC (2009).
Undamaged cotton plants yield more if their neighbour is damaged: implications for pest management.
Bulletin of Entomological Research 99, 467-478

Wu H, Walker S, Rollin M, Tan D, Robinson G & Werth J (2007).
Germination, emergence and persistence of flaxleaf fleabane (Conyza bonariensis).
Weed Biology and Management 7, 192-199.

Wu H, Walker S, Robinson G & Coombes N (2010).
Competition of sorghum cultivars and densities with Japanese millet.
Weed Biology and Management 10, 185-193

Wu H, Walker S & Robinson G (2008).
Chemical control of flaxleaf fleabane (Conyza bonariensis (L.) Cronquist).
Plant Protection Quarterly 23, 162-165.

Xu J, De Barro PJ & Liu SS (2010).
Reproductive incompatibility among genetic groups of Bemisia tabaci supports the proposition that the whitefly is a cryptic species complex.
Bulletin of Entomological Research 100, 359-366.

Yeates SJ, Constable GA & McCumstie T (2005).
Cotton growth and yield after seed treatment with mepiquat chloride in the tropical winter season.
Field Crops Research 93, 122-131.

Yeates SJ, Constable GA & McCumstie T (2010).
Irrigated cotton in the tropical dry season. I: Yield, its components and crop development.
Field Crops Research 116, 278-289.

Yeates SJ, Constable GA & McCumstie T (2010).
Irrigated cotton in the tropical dry season. II: Biomass accumulation, partitioning and RUE .
Field Crops Research 116, 300-307.

Yeates SJ, Constable GA & McCumstie T (2010).
Irrigated cotton in the tropical dry season. III: Impact of temperature, cultivar and sowing date on fibre quality.
Field Crops Research 116, 300-307.

Yuan M, Liu B, Liu EM, Sheng W, Zhang Y, Crossan A, Kennedy I, Wang S (2011).
Immunoassay for phenylurea herbicides: Application of molecular modeling and quantitative structure-activity relationship analysis on an antigen-antibody Interaction study.
Analytical Chemistry 83, 4767-4774.

Yunusa IAM, Manoharan V, Odeh IOA, Shrestha S, Skilbeck CG, Eamus D (2011).
Structural and hydrological alterations of soil due to addition of coal fly ash.
Journal of Soils and Sediments 11, 423-431.

Zehnder G, Gurr GM, Kuhne S, Wade MR, Wratten SD & Wyss E (2007).
Arthropod pest management in organic crops.
Annual Review of Entomology 52. 57-80.

Publications report

Refereed conference proceedings

Andersen MS & Acworth RI (2007).

Surface water groundwater interactions in an ephemeral creek in the Namoi Valley, NSW, Australia – Controls by geology and groundwater abstraction.

Proceedings of the XXXV IAH Congress Groundwater and Ecosystems Lisbon. September, 2007.

Andersen M.S., Acworth R.I. (2007):

Hydrochemical investigations of surface water groundwater interactions in a sub-catchment in the Namoi Valley, NSW, Australia.

Proceedings of the XXXV IAH Congress Groundwater and Ecosystems, Lisbon. September, 2007.

Andersen MS, Meredith K, Timms W & Acworth RI (2008).

Investigation of δ18O and δ2H in the Namoi River catchment – elucidating recharge sources and the extent of surface water/groundwater interaction.

XXXVI IAH Congress Toyama, Japan 26th of October - 1st of November 2008.

Andersen MS, McCallum AM, Meredith K & Acworth RI (2010).

Investigation of recharge pathways and recharge rates using environmental isotopes (2H, 18O, 14C and 3H) in the Maules Creek Catchment, NSW, Australia.

XXXVIII - IAH Congress, Krakow, Poland. 12-17 September, 2010.

Badenhop A, Timms WA, Kelly BFJ, Witts B, Rayner D & Mehrabi S. (2011)

Are groundwater salinity changes in the Namoi catchment leading to the degradation of beneficial uses? NSW IAH Symposium 2011 Hydrogeology in NSW – the Challenge of Uncertainty.

5-6 September, Dockside, Sydney.

Bahar H, Stanley J, Gregg PC & del Socorro A. (2009).

Do green lacewings (Mallada signata) feed more on Helicoverpa armigera on transgenic Bt Cotton? Tropentag2009, 6-8 October 2009, Hamburg, Germany, p. 139

Available Online at: http://www.tropentag.de/abstract.php?code=SVOjtrCP

Baker GH (2010).

Influence of earthworms on the growth of cotton and wheat plants in contrasting soil types. Proceedings of the 19th World Congress Soil Science: Soil solutions for a changing world, 1-6 August 2010, Brisbane, Australia.

Available online at: www.19wcss.org.au

Baker G & Tann C. (2007).

Mating of Helicoverpa armigera (Lepodoptera: Noctuidae) moths in relation to their plant hosts as larvae within Australian cotton farming systems.

Proceedings of the 4th World Cotton Research Conference, 10-14 September 2007, Lubbock, Texas, 1603-1610.

Bange MP, Milroy SP & Roberts GN (2006).

Factors Influencing crop maturity

Beltwide Cotton Conference 2-5 January 2006, San Antonio, Texas.

Bange MP, Roche R & Caton SJ (2006).

Impact of row configuration on high fruit retention (transgenic) rain-fed cotton systems.

13th Australian Agronomy Conference, 10-14 September 2006, Perth, Australia,

Bella LP, Rixon C, Armytage P, Davies B, Dorahy K, Wood AW & Sheedy P (2007).

The 2006 Herbert MODDUS pilot Program.

2007 Conference of the Australian Society of Sugar Cane Technologists , 8-11 May 2007, Cairns, Australia,

Bhattarai SP & Midmore DJ (2005).

Influence of soil moisture on yield and quality of tomato on a heavy clay soil .

Proceedings of the international symposium on harnessing the potential of horticulture in the Asian-Pacific Region, 451-454.

Blakers RS, Kelly BFJ, Anderssen R, Mariethoz G & Timms W. (2011).

3D Dendrogram Analysis for Mapping Aquifer Connectivity and Flow Model Structure. MODFLOW and More 2011:

Integrated Hydrologic Modeling, Colorado School of Mines, Golden, Colorado, June 5 - 8, 2011.

Brodrick R and Bange M (2010).

Determining physiological cut-out in ultra narrow row cotton systems. In: Proceedings of the 15th Australian Agronomy Conference, 15-18 November 2010. Lincoln, New Zealand.

http://www.regional.org.au/au/asa/2010/crop-production/plant-density/6970_brodrickr.htm

Coleman D, Gupta VVSR, Jangid K, Wakelin S & Whitman W (2010).

The composition and diversity of prokaryotoic and eukaryiotic communities from an Australian vertisol: an experimental study. Proceedings of the 19th World Congress of Soil Science; Soil Solutions for a Changing World. August 1 – 6, 2010.

Brisbane, Australia, 231-234. http://www.iuss.org,

Charles, GW & Taylor IN (2007).

Developing a threshold model for controlling weeds in glyphosate resistant cotton.

Proceedings of the 4th World Cotton Research Conference, 10-14 September 2007, Lubbock, USA, 1541-1563.

Constable G & Bange M (2007).

Producing and preserving fibre quality: from the seed to the bale.

Proceedings of the 4th World Cotton Research Conference, 10-14 September 2007, Lubbock, Texas, USA, 2168-2182.

Cottee NS, Tan D, Bange MP & Cheetham JA (2007).

Simple electrolyte leakage protocols to detect chilling tolerance in cotton genotypes.

4th World Cotton Research Conference, 10-14 September 2007, Lubbock, USA, 1700-1711.

Cottee NS, Tan D, Cothern JT, Bange MP & Campbell LC (2007).

Screening cotton cultivars for thermotolerance under field conditions

4th World Cotton Research Conference , 10-14 September 2007, Lubbock, USA, 2234-2246.

Coumans JV, Perek-Gerk L, Aitken EA, Nehl DB & Harvey JA (2006).

Proteomic and genetic investigation of Thielaviopsis isolates exhibiting differenct levels of pathogenicity towards cotton (Gossypium hirsutum).

11th Proteomic Symposium, 3-5 February 2006, Lorne.

Dalton B, McIntyre GI,Gibb D,Hickman M & Kauter G (2008).

Australian Cotton Cooperative Research Centre IPM short courses – An industry learning together.

Proceedings of the World Cotton Research Conference 3, Capetown South Africa. 2008

Del Socorro AP & Gregg PC (2007).

Responses to plant volatiles by the green mirid, Creontiades dilutus. Second International Lygus Bug Symposium, 15-19 April 2007, Pacific Grove, CA, USA.

Abstract published in Journal of Insect Science 8/Article 49. http://insectscience.org/8.49/i1536-2442-8-49.pdf

Publications report

Del Socorro AP, Lowor ST & Gregg PC (2007).

Sex pheromones of the green mirid, Creontiades dilutus. Second International Lygus Bug Symposium, 15-19 April 2007, Pacific Grove, CA, USA.

Abstract published in Journal of Insect Science 8/Article 49. http://insectscience.org/8.49/i1536-2442-8-49.pdf

Devereux AF, Fukai S & Hulugalle NR (2008).

The effects of maize rotation on soil quality and nutrient availability in cotton based cropping. In "Global Issues – Paddock Action.

14th Australian Agronomy Conference, 21-25 September 2008, Adelaide, SA, Australia.

Dorahy K, Aubert A, Rixon C, Davies B, Armytage P, Bella LP & Butler G (2007).

A risk sharing model as a way of delivering productivity gains for the Australian sugar industry.

2007 Conference of the Australian Society of Sugar Cane Technologists, 8-11 May 2007, Cairns, Australia, 377-384.

Duggan B & Wilson L (2007).

The response of cotton to real and simulated mirid damage in Australia.

Proceedings of the World Cotton Research Conference 4, 10-14 September 2007, Lubbock, Texas, USA, 1684-1696.

Errington M, Campbell L, Rochester I & Tan D (2007).

Efficacy of Foliar Fertilization in Cotton.

Proceedings of the 4th World Cotton Conference, 10-14 September 2007, Lubbock, Texas, USA, 1686-1696.

Fitt, G.P. and Wilson L.J. (2005)

Integration of Bt cotton in IPM systems: an Australian perspective. Second International Symposium on Biological Control of Arthropods, 12-16 September 2005, Davos, Switzerland 382-389.

Available online at http://www.bugwood.org/arthropod2005

Fitt G (2007).

Global Resistance Management Strategies for Bt cotton.

Proceedings of the 4th World Cotton Conference, 10-14 September 2007, Lubbock, Texas, USA, 2169-2179.

Fitt GP & Wilson L (2005).

Integration of Bt cotton in IPM systems: an Australian perspective.

Second International Symposium on Biological Control of Arthropods, 12-16 September 2005, Davos, Switzerland, 381-388.

Foley JL, Silburn DM & Greve A. (2010).

Resistivity imaging across native vegetation and irrigated Vertosols of the Condamine catchment—a snapshot of changing regolith water storage. Proceedings of the 19th World Congress of Soil Science: Soil solutions for a changing world. 1-6 August 2010, Brisbane, Australia.

Available online at: www.19wcss.org.au

Ghosh S, Lockwood P, Daniel H, Hulugalle N, King K & Kristiansen P (2008).

Soil quality changes and affordability of applying organic amendments to a vertosol from Northwestern NSW, Australia.

Proceedings of the Joint Conference of Australian and NZ Soil Science Societies 1-5 December 2008, Palmerston North, New Zealand.

Giambastiani BMS, Kelly BFJ, The C, Andersen MS, McCallum AM & Acworth RI (2009)

3D Time and Space Analysis of Groundwater Head Change for Mapping River and Aquifer Interactions.

18th World IMACS / MODSIM Congress, 13-17 July, Cairns, Australia. http://mssanz.org.au/modsim09

Gordon S, Long R, Bange MP, Lucas S & Phair-Sorensen N (2007).

Measurement of average maturity and maturity distribution statistics by Siromat in cotton fibre picked from plants subjected to defoliation timing treatments.

Beltwide Cotton Conference, New Orleans, USA.

Green TD, Sindel BM, Werth J & Charles G (2008).

A review of the ecology of fleabane (Conyza s) in Australia.

16th Australian Weeds Conference, Cairns, 18-22 May 2008, Cairns, Australia, 171-173.

Gregg P (2007).

Biology, ecology and management of the green mirid, Creontiades dilutus (Stål) in Australia. Second International Lygus Bug Symposium, 15-19 April 2007, Pacific Grove, CA, USA.

Abstract published in Journal of Insect Science 8/Article 49. http://insectscience.org/8.49/i1536-2442-8-49.pdf

Greve A & Acworth RI (2008).

Monitoring depth of soil cracking win irrigated elds based on directional dependence of electrical current flow.

36th IAH Congress, 26 October-1 November 2008, Toyama, Japan.

Greve A & Acworth RI (2010).

Monitoring soil moisture changes and deep drainage pathways

37th IAH Congress, 6-10 September 2010, Hyderabad, India.

Greve A, Acworth RI & Kelly B (2008).

Monitoring soil moisture changes with 3D resistivity tomography.

Western Pacific AGU meeting, 28 July-1 August 2008, Cairns, Australia.

Heller GZ, Stasinopoulos DM, Rigby RA & van Ogtrop FF (2009).

Randomly stopped sum models: a hydrological application.

24th international workshop for statistical modelling, 20-24 July 2009, New York, USA.

Herron N & Croke B (2007).

Including the Influence of groundwater exchanges in a lumped rainfall-runoff model. MODSIM 2007 International Congress on Modelling and Simulation, 10-13 December 2007, Christchurch, New Zealand, 1436-1442

Available Online at: http://www.mssanz.org.au/MODSIM07/papers/23_s31/IncludingTheInfluence_s31_Herron_.pdf

Herron N & Croke B (2009)

A 3-store formulation for modelling groundwater-surface water interactions.

18th World IMACS/MODSIM Congress, 13-17 July 2009, Cains, Australia.

Higgerson G, Le C, Long R, Lucas S, Naylor G & Purmalis M (2007).

Inter-laboratory evaluation of the cottonscan instrument for determining average fibre linear density (fineness) of cotton lint samples.

Proceedings of the 4th World Cotton Research Conference, 10-14 September 2007, Lubbock, U.S.A., 1685-1697.

Publications report

Hollingsworth I & Odeh IOA (2009).

Simulation and assessment of mine landscape reconstruction using analogue landform and environmental design criteria.

IEEE Transactions of the 2nd International Conference on Environmental and Computer Science (ICECS 2009), Dubai, December 28-30, 2009. pp 62-65.

Hollingsworth I, Odeh IOA, Bui E & Croton J (2007).

Planning for closure at Ranger Mine - landscape reconstruction using natural analogs.

Proceedings of the International Mining Symposium WISMUT 2007 Mine Closure and Sustainable Development of Rehabilitated Mining Areas.

Gera Germany, September 10-12, 2007. pp 543-550. Editors: M. Paul, P Mattig, H. Metzner. Publisher Wismut GmbH, Jagdschankenstrasse 29, 09117 Chemnitz.

House AP, Schellhorn NA, Brown SD & Bianchi FJ (2007).

Landscape configuration, vegetation condition and ecosystem services in cotton agro-ecosystems in southern Queensland, Australia. 25 Years of Landscape Ecology: Scientific Principles and Practice,

8-12 July 2007, Wageningen, The Netherlands, 86-87.

Hulugalle NR, McCorkell BE & Hickman M (2006).

Changes in soil salinity, sodicity and organic carbon due to sowing irrigated cotton into standing or incorporated wheat stubble in a saline/sodic Vertosol.

Joint Conference of Australian Society of Soil Science Inc., and Australian Soil and Plant Analysis Council, 3-7 December 2006, Adelaide, SA, Australia, p. 31

Hulugalle N, Weaver T, Finlay L, Luelf N & Tan D (2009).

Potential contribution by cotton roots to soil carbon stocks in furrow-irrigated Vertisols of NW New South Wales, Australia.

7th SYmposium of International Scoiety for Root Research, 2-4 September 2009, Vienna, Austria.

Hulugalle NR & Scott F (2006).

Rotation crops for cotton sown on permanent beds in irrigated Vertisols.

17th Triennial Conference of the International Soil Tillage Research Organisation, 28 August-3 September 2006, Kiel, Germany, 687-691.

Hulugalle NR, Weaver TB, Finlay LA, Broughton K & Tan DK (2010).

Potential contribution by corn and Bollgard II cotton roots to soil carbon stocks in a furrow-irrigated Vertisol. Proceedings of the 19th World Congress on Science: Soil solutions for a changing world.

1-6 August 2010, Brisbane, Australia. Available online at:www.19wcss.org.au

Hulugalle NR, Weaver TB & Finlay LA (2010).

Drainage under permanent beds in a furrow-irrigated Vertisol. Proceedings of the 19th World Congress of Soil Science: Soil solutions for a changing world.

1-6 August 2010, Brisbane, Australia. Available online at: www.19wcss.org.au

Karanja F (2007).

Evaluating the impact of integrated catchment management interventions on provision of ecosystem services using GIS. 25 years Landscape Ecology: Scientific Principles in Practice.

Proceedings of the 7th IALE World Congress, 8-12 July, Wageningen, The Netherlands. , 8-12 July 2007, Wageningen, The Netherlands, 1034-1035.

Kelly BFJ (2009)

Catchment scale 3D geological models from sparse data sets. International Mathematica User Conference 2009, October 22-24, 2009, Champaign, Illinois, USA.

http://www.wolfram.com/news/events/userconf2009/presentations.html

Kelly BFJ & Giambastiani BMS (2009)

Functional programming algorithms for constructing 3D geological models. In Lees, B.G. & Laffan, S.W. (eds),

10th International Conference on GeoComputation, The University of New South Wales, Sydney, 30th November- 2nd December, 2009. http://www.biodiverse.unsw.edu.au/geocomputation/proceedings/

Keenan MD, Walker S & Widderick M (2008).

Barnyard grass responses to glyphosate - the importance of morphological traits.

16th Australian Weeds Conference, 18-22 May 2008, Cairns, Queensland, 483-486.

Keenan MD, Walker S & Widderick M (2006).

Morphology and molecular characterisation of Echinochloa species in the northern grain region.

15th Australian Weeds Conference , 24-28 September 2006, Adelade, South Australia, 133-136.

Khan M. Quade,A, & Murray D (2008).

Reduced rate of chemical plus additive- and effective IPM tool for managing mirids, Creontiades s in Australian cotton.

Journal of Insect Science (online) 8/49). www.insectscienec.org/papers Goodell PB & Ellsworth PC (ed). Second International Lygus Symposium, Asilomar Conference Center, Pacific Grove, CA USA.

Khan M, Quade A & Murray D (2008).

Damage assessment and action threshold for mirids, Creontiades s in Bollgard® II cotton in Australia.

Journal of Insect Science (online) 8(49). www.insectscience.org/papres Goodell PB & Ellsworth PC (ed). Second International Lygus Symposium, Asilomar Conference Center, Pacific Grove, CA USA.

Knox OG & Gupta VVSR (2005)

Evaluation of border cell number and Cry protein expression from root tips of Gossypium hirsutum.

6th Pacific Rim Conference on the Biotechnology of Bacillus thuringiensis andits Environmental impact, Cote, J.-C, Otvos, I.S., Schwartz, J.-L and Vincent, C. (eds.) Victoria, BC, Canada, : 139-140.

Koech RK, Gillies MH & Smith RJ (2010).

Simulation modelling in surface irrigation systems.

Southern Region Engineering Conference, 10-12 November 2010, Toowoomba, Australia, 8.

Koech RK, Smith RJ & Gillies MH (2010).

Automation and control in surface irrigation systems: Current status and expected future trends.

Southern Region Engineering Conference, 10-12 November 2010, Toowoomba, Australia, 7.

Luelf N, Tan D, Hulugalle N, Knox O, Weaver T & Field D (2006).

Root turnover and microbial activity in cotton farming systems.

13th Australian Agronomy Conference, Gold Coast, Australia.

McCallum AM, Andersen MS, Kelly BFJ, Giambastiani BMS & Acworth RI (2009)

Hydrologic investigations of surface water groundwater interactions in a sub-catchment in the Namoi Valley, NSW, Australia. In Taniguchi M et al. (eds.), Trends and Sustainability of Groundwater in Highly Stressed Aquifer.

Proceedings of Symposium JS.2 at the Joint IAHS & IAH Convention, Hyderabad, India, September 2009., vol. 329: 157-166.

Publications report

McCallum A, Andersen MS, Rau G & Acworth RI (2010):

Investigation of surface water groundwater interactions and temporal variability of streambed hydraulic conductivity using streambed temperature data.

XXXVIII - IAH Congress, Krakow, Poland. 12-17 September, 2010.

McIntyre G (2007).

Modern Extension and transfer methodologies: Public and private perspectives and approaches in Australia.

Proceedings of the 4th World Cotton Research Conference, 10-14 September 2007, Lubbock, Texas, USA, 2128-2138.

McIntyre G, Chapman V & Maas S (2007).

Integrating natural resource management into mainstream extension in the Australian Cotton industry through partnerships.

Proceedings of the 4th World Cotton Conference, 10-14 September 2007, Lubbock, Texas, USA, 1699-1706.

McIntyre GT, Gibb D, Shaw AJ, Christiansen IH & Pyke BA (2008).

Extension in the Australian cotton industry - a team approach.

Proceedings of the World Cotton Research Conference 3, Capetown South Africa. 2008.

McIntyre, GT & Goyne PJ (2008).

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

Proceedings of the World Cotton Research Conference 3, Capetown South Africa. 2008.

Manandhar R., Odeh IOA & Ancev T (2009).

Modelling of spatio-temporal expansion of built-up and residential-commercial dwelling and their socioeconomic implications in the Lower Hunter of NSW, Australia. In: Ostendorf B, Baldock P, Bruce D, Burdett M & Corcoran P (eds.),

Proceedings of Surveying and Spatial Sciences Institute Biennial International Conference, Adelaide September 29- October 2, 2009, Surveying & Spatial Institute, 277-292.

Mansfield S & Hagler JR (2009)

Using existing methods in new ecosystems - can we just plug and play?

Proceedings of the 3rd International Symposium on Biological Control of Arthropods, Christchurch, New Zealand, 8-13 February, 2009, 469-474.

Mensah RK, Austin L & Anderson S (2011).

Entomopathogenic fungus: A new biopesticide for managing Creontiades dilutus and Bemisia tabaci infestations on commercial transgenic cotton crops.

Proceedings of the World Cotton Conference 5, Mumbai, India, 7-11 November 2011. 8.

Nejem J, Yates D & Merrick N (2009).

Analytical solutions in coupled streamflow and groundwater modelling. 32nd Hydrology and Water Resources Symposium "H2009: Adapting to Change",

30 November-3 December 2009, Newcastle, Australia, 323-332.

Nelson MA, Odeh IOA, Bishop TFA & Weber N (2010).

Quantifying the uncertainty in digital soil class maps developed using model-based approaches

Proceedings of the 19th World Congress of Soil Science. Brisbane. Working Group 1.3 Digital Soil Assessment. 42–45.

Nelson MA, Odeh IOA, Bishop TFA & Weber N (2009).

A generalized linear spatial model for digital soil class mapping Digital soil class mapping using Model-based geostatistics.

In Proceedings of the Pedometrics 2009 Conference, Biennial Meeting of Commission 1.5 Pedometrics, IUSS, Beijing. 60–61.

Osten V, Wu H, Walker S, Wright G & Shields A (2006).

Weeds and summer crop row spacing studies in Queensland.

15th Australian Weeds Conference, 25-28 September 2006, Adelaide, Australia, 347-50.

Patterson J, Andersen MS & Acworth RI (2008).

Development of an integrated conceptual model of a connected surface water-groundwater system using a hydrochemical approach at Maules Creek, NSW, Australia.

XXXVI IAH Congress Toyama, Japan 26 October - 1 November 2008.

Paytas M, Fukai S & Yeates S (2009).

Effect of early water stress on flower bud removal and development of high retention cotton.

InterDrougnt - III Conference, 11-16 October 2009, Shanghai, China.

Paytas M, Yeates S, Fukai S & Huang L (2007).

Early production of biomass in high retention cotton.

Proceedings of the 4th World Cotton Research Conference, 10-14 September 2007, Lubbock, USA. Available Online at: http://www.wcrc4.org

Pendergast L & Midmore DJ (2006).

Oxygation: Enhanced root function, yields and water use efficiencies through aerated subsurface drip irrigation, with a focus on cotton.

13th Australian Society of Agronomy Conference, 10-14 September 2006, Perth, Australia. Available Online at: http://www.regional.org.au/au/asa/2006/concurrent/technology/4702_pendergastl.htm

Rau G, Andersen MS, McCallum A & Acworth RI (2010):

Uncertainty of vertical streambed seepage rates under realistic field conditions using diel temperature fluctuations.

XXXVIII - IAH Congress, Krakow, Poland. 12-17 September, 2010.

Robinson JB, Silburn DM, Foley JL & Orange D (2010).

Root zone soil moisture content in a Vertosol is accurately and conveniently measured by electromagnetic induction measurements with an EM38.. 19th World Congress of Soil Science: Soil solutions for a changing world.

1-6 August 2010, Brisbane, Australia, Available online at: www.19wcss.org.au

Roche R & Bange M (2006).

Do ultra-narrow row cotton systems offer any benefits to Australian farmers?. Proceedings of the 13th Australian Agronomy Conference, Perth. Australian Society of Agronomy, 10-15 September 2006, Perth, Australia, 5

Available Online at: http://www.regional.org.au/au/asa/2006/concurrent/systems/4568_rocher.htm

Schellhorn NA & Bianchi FJJA (2010).

The role of forests in capturing the ecosystem service of pest control: a pathway to integrate pest control and biodiversity conservation. In: The role of forest biodiversity in the sustainable use of ecosystem goods and services in agro-forestry, fisheries, and forestry.

OECD Proceedings of International Symposium for the Convention on Biological Diversity Tokyo, Japan 43-49.

Terry JH, Tan DK, Hulugalle NR, Field DJ, Weaver TB & Knox OG (2008).

Cotton yield and soil carbon under continuous cotton, cotton-corn, cotton-vetch-corn and cotton-wheat rotations.

14th Australian Agronomy Conference, 21-25 September 2008, Adelaide, SA, 21-25 September 2008, Adelaide, South Australia.

Thornby D, Walker S & Whish J (2008).

Modelling to estimate glyphosate resistance risk in barnyard grass in the northern Australian grain region.

16th Australian Weeds Conference, 18-22 May 2008, Cairns, Australia, 513-515

Thornby D, Walker S & Whish JP (2006).

Simulating weed persistence and herbicide resistance in the northern grain region using a validated crop growth model with extensions for seedbank dynamics and mating.

15th Australian Weeds Conference, 24-28 September 2006, Adelade, South Australia, 499-502.

Thornby D, Werth J Walker S (2010).

Risks and RATs: assessing glyphosate resistance risk in paddocks in north-eastern Australia.

17th Australasian Weeds Conference, 26-30 September 2010, Christchurch, New Zealand.

Timms W, Kelly BFJ, Blakers R, Farley C, Regmi G, Larsen J & Bowling A (2011)

Implications of 3D geological architecture for surface-groundwater connectivity in the Mooki catchment.

NSW IAH Symposium 2011 Hydrogeology in NSW – the Challenge of Uncertainty. 5-6 September, Dockside, Sydney.

van Ogtrop FF, Vervoort RW, Heller GZ, Stasinopoulos DM & Rigby RA (2009).

Long-range Forecasting of intermittent streamflow using a regression framework.

h2009, 30 November-3 December 2009, Newcastle, Australia.

Vanags C & Vervoort RW (2006).

Simulation of the hydrological behaviour of a paleochannel system under irrigation: implications for management at the local and catchment scale.

ICHWAM Conference Hyderabad (India), 5-8 December 2006, Hyderabad, India.

Walker S & Robinson G (2008).

Flaxleaf fleabane - the next glyphosate resistant weed?

16th Australian Weeds Conference, 18-22 May 2008, Cairns, Australia, 88-90.

Walker S, Wilson B & Wu H (2006).

Weed seed persistance with changing farming practices in sourthern QLD.

15th Australian Weeds Conference, 24-28 September 2006, Adelaide, South Australia, 343-346.

Wang X, Lester D, Guppy C, Lockwood P, Tang,C & Sale P (2006).

Changes in phosphorus fractions at various soil depths after long-term continuous cultivation on a Black Vertosol.

ASSSI-ASPAC-ACMS National Soils Conference, 3-7 December 2006, Adelaide, Australia.

Wang X, C Tang, CN Guppy, PWG Sale (2010)

Phosphorus acquisition characteristics of cotton (Gossypium hirsutum L.) plant: a review.

Proceedings of the 19th World Congress of Soil Science; Soil Solutions for a Changing World; Brisbane, Australia: IUSS; 1-6 August 2010. Avaialble online at http://www.iuss.org

Werth J, Thornby D, Walker S, Boucher L & Charles G (2010).

Species shift and resistance: Challenges for Australian cotton systems.

17th Australasian Weeds Conference, 26-30 September 2010, Christchurch, New Zealand.

Werth J, Widderick M & Osten V (2008).

Prolonging glyphosate effectiveness on difficult to control summer weeds.

16th Australian Weeds Conference, 18-22 May 2008, Cairns, Queensland, 288-290.

Werth J, Preston C, Baker J, Roberts G & Taylor I (2006)

Predicting the rate of glyphosate resistance evolution in glyphosate tolerant cotton systems in Australia.

Managing weeds in a changing climate 15th Australian Weeds Conference, 24-28 September 2006, Adelaide, South Australia. 503-506.

Whitehouse M, Mansfield S, Hagler J, Nobilo J & Harden S (2009).

The use of ELISA techniques to clarify predator/prey interactions in cotton.

Proceedings of the 3rd International Symposium on Biological Control of Arthropods, 27 April 2009, Christchurch, New Zealand.

Whitehouse M, Wilson LJ, Fitt GP & Constable GA (2009).

Integrated Pest Management and the effects of transgeneic cotton on insect communities in Australia: lessons from the past and future directions.

Proceedings of the 3rd International Symposium on Biological Control of Arthropods, 27 April 2009, Christchurch, New Zealand.

Widderick M, Walker S & Storrie A (2006).

Herbicide resistance prevention and management in the northern cropping region through extension and education.

15th Australian Weeds Conference, 24-28 September 2006, Adelaide , South Australia, 491-494.

Wu H, Walker S, Osten V & Robinson G (2008).

Competitive ability of some sorghum cultivars and densities on weed suppression.

18-22 May 2008, Cairns, Australia.

Wu H, Walker S, Taylor I & Robinson G (2006).

Biology and management of flaxleaf fleabane.

15th Australian Weeds Conference, 25-28 September 2006, Adelaide, Australia, 137-140.

Wu H, Walker S & Osten V (2008).

Competitive effects of sorghum cultivars and densities on weed suppression.

16th Australian Weeds Conference, 18-22 May 2008, Cairns, Queensland, 483-486.

Wu H, Walker S & Taylor I (2006).

Biology and management of flaxleaf fleabane (Conyza bonariensis(L.) Cronquist).

15th Australian Weeds Conference, 24-28 September 2006, Adelaide , South Australia, 137-140.

Yeates S, Richard D, Roberts J & Gregory R (2006).

Process in evaluating the moisture stress response of Bollgard II compared with conventional cotton.

13th Australian Cotton Conference, 8-10 August 2006, Brisbane, Australia, 627-631.

Publications report

Non-refereed journal articles

Adcock L (2008).
A new era for BMP.
The Australian Cottongrower 29 (2), 8.

Anderson C & Nehl D (2006).
Research finds Fusarium floats.
The Australian Cottongrower. 27, 10-12.

Bagshaw K (2010).
Cleaner modules create favourable processing settings for higher returns.
The Australian Cottongrower. 31 (2), 32-34.

Bagshaw MK, Gordon GS & Horne AF (2010).
The effect of lint cleaning on cotton fibre quality.
The Australian Cottongrower 30 (4), 34-38.

Bahar H, Stanley J, Gregg PC & del Socorro AP (2009).
Catching Helicoverpa survivors on Bollgard II with green lacewing.
The Australian Cottongrower. 30 (6), 12-14.

Bange M, Milroy S & Hearn B (2005).
Performance of simulated dryland skip-row cotton.
The Australian Cottongrower 25, (7) 58-60.

Bange M, Milroy S & Roberts G (2006).
Managing for crop maturity.
The Australian Cottongrower 27 (7) 53-56.

Bange M, Roche R, Caton J & Hodgson D (2008).
Does Bollgard II Perform Differently in dryland systems?.
Australian Cottongrower, 29, (7) 36-39.

Bange M, Constable G, Gordon S, Long R, Nalyor G & van der Sluijs, M (2010).
Pre-sowing considerations to preserve fibre quality.
The Australian Cottongrower 31 (3), 12-16.

Bange M, Constable G, Gordon S, Long R, Naylor G & van der Sluij, M (2010).
Preparing for harvest to preserve fibre quality.
The Australian Cottongrower 31 (1), 10-14.

Bange M & Brodrick R (2010).
Do sowing rules change for Bollgard II cotton?
The Australian CottonGrower 31, (4) 11-14.

Bange M, Milroy S & Roberts G (2006).
Managing for crop maturity.
The Australian Cotton Grower. 27 (7), 53-56.

Bange MP, Constable G, Gordon S & Long R (2010).
The impact of early defoliation on neps.
The Australian Cottongrower 30 (4), 39-41.

Bange MP, Constable G, Gordon S & Long R. (2011).
Measuring the maturity of developing cotton fibres.
The Australian Cottongrower 31 (7), 334-36.

Bange MP, Constable G, Gordon S, Long R, Naylor G & Van der Sluijs M (2011).
In-season considerations to preserve fibre quality.
The Australian Cottongrower 31 (7), 38-41.

Braunack M, Price J & Hodgson D (2011).
The effect of picker traffic on soil compaction: a preliminary survey.
The Australian Cottongrower 32 (7), 12-16.

Brotherton E. (2006).
Siphon-less irrigation systems: So how do they perform?
Australian Cotton Grower 27 (3), 44-46.

Brotherton E (2006).
Which Irrigation System?
The Australian Cotton Grower. 21 (2), 54.

Brotherton E, Harris G, Smith P & Wigginton D (2008).
Deep drainage myth-busters.
The Australian Cottongrower 29 (4), 38-42.

Buchanan S & Triantafilis J (2005).
Wet roots?- a groundwater mapping case study at Bourke.
Australian Cottongrower 26 (3), 60.

Buchanan SM & Triantafilis J (2009).
Mapping water table depth using geophysical and environmental variables.
Ground Water 47, (1), 80-96.

Carrigan E, Harris GA & Hood S (2007).
The challenge of a new lateral move or centre pivot.
The Australian Cottongrower 28 (1), 16-20

Charles G (2008).
How well does the critical period for weed control (CPWC) work?
The Australian Cottongrower 29 (7), 40-42.

Charles G (2009).
It's all phenoxy.
The Australian Cottongrower. 30 (7), 10-14.

Charles G (2010).
It's all Phenoxy.
The Australian Cottongrower. 31 (7), 38-39.

Charles G (2009).
Planning weed management decisions in cotton.
The Australian Cottongrower 30 (7), 38-39.

Charles G (2006).
WEEDpak updated with new management tools.
The Australian Cottongrower 27 (4), 20.

Charles G (2010).
Residual herbicides- the hidden cost!
The Australian Cottongrower 31 (6), 22-23.

Charles G & Taylor I (2007).
Understanding the "critical period for weed control" concept.
The Australian Cottongrower 28 (4), 48-50.

Charles G & Taylor I. (2007).
Applying the "critical period for weed control" in the field.
The Australian Cottongrower 28 (4), 51-53.

Charles G, Taylor I & Farrell T (2008).
Roundup Ready Flex and the critical period for weed control.
Australian Cottongrower 29 (1), 38-43.

Charleston K, Addison S, Miles M & Maas S (2010).
The Solenopsis mealybug outbreak in Emerald.
The Australian Cottongrower 31 (2), 18-22.

Clancy L, Constable G & Stiller W (2011).
Dryland cotton water use efficiency on the increase.
The Australian Cottongrower 30 (4), 11-14.

Constable G & Bange M (2006).
What is cotton's sustainable yield potential?
The Australian Cottongrower, 26 (7), 6-10.

Cross L (2005).
Natural resource management: Achieving more through partnerships.
The Australian Cottongrower. June - July 2005. 26 (3), 47 - 56.

Publications report

Crossan A, Kennedy I & Van der Sluijs R (2011).
Pesticide residues in Australian cotton and cotton seed.
The Australian Cottongrower 31 (7), 42-45

Dayal A, Deutscher S & Bange M (2007).
New generation scouting tools.
The Australian Cottongrower 28 (3), 23-24.

Deutscher S, Rochester I & Clancy L (2006).
Major upgrade for cotton nutrition tools.
The Australian Cottongrower. 27 (7), 46.

Downes S, Rossiter L, Farrell T, Wilson L & Kauter G (2005)
Managing resistance: Your IRMS and RMP questions answered.
The Australian Cottongrower 26(6), 10-14

Downes S, Rossiter L, Parker T, McKenzie F & Staines T (2007).
How to collect Helicoverpa for resistance testing.
The Australian Cottongrower, 28 (7). 48-49.

Downes S, Mahon R, Rossiter L., Farrell T, Wilson L. & Kauter G (2006)
How will drought affect Helicoverpa resistance management.
The Australian Cottongrower 27 (7), 60-62.

Ghosh S, Hulugalle N, Daniel H & Lockwood PV (2007).
Do organic amendments improve soil quality?
The Australian Cottongrower, 28 (3), 46-48.

Gordon B (2005).
Why are we still having problems with spray drift?
The Australian Cottongrower, 26 (2), 24-26.

Gordon S, Horne S & van der Sluijs M (2009).
Moisture in cotton - the fundamentals.
The Australian Cottongrower, 30 (7), 32-35.

Gordon S, van der Sluijs M & Horne S (2010).
The importance of moisture during ginning.
The Australian Cottongrower. 31 (3), 34-39

Gordon S, van der Sluijs M, Krajewski A & Horne S (2010).
Measuring moisture in cotton.
The Australian Cottongrower. 31 (1), 38-42.

Goyne PJ & McIntyre GT (2002).
Stretching water- Queensland's water use efficiency cotton and grains Adoption Program.
Water Science and Technology 48 (7), 191-196.

Gregg P & del Socorro A (2010).
Magnet - potential roles in management of resistance to Bt.
The Australian Cottongrower, 31 (3), 22-24.

Grundy P (2009).
Burdekin cotton on top of the pack.
The Australian Cottongrower, 30 (7), 16-18.

Grundy P & Braden B (2007).
Who is growing cotton in the Burdekin?
The Australian Cottongrower, 28 (6), 13-15.

Grundy P & Yeates S (2007).
Is a sustainable cotton industry possible in the Burdekin?
The Australian Cottongrower, 28 (6), 16-20.

Grundy P, Yeates S & Woods J (2009).
Burdekin research update.
The Australian Cottongrower, 30 (6), 18-23.

Hare J & Harris G (2008).
Leaky storages - What are the options?
The Australian Cottongrower, 29 (2), 34-38.

Hare J & White S (2007).
Variety and irrigation strategy: results from a Darling Downs trial.
The Australian Gottongrower, 28 (7), 22-25

Harris G, Chudleigh F & Shaw A (2007).
Sprinkler irrigation: profitable or not?
The Australian Cottongrower, 28 (3), 40-43.

Harris G (2008).
Cotton CRC given green light for on-farm storages project.
The Australian Cottongrower 29 (4), 45

Harris G (2007).
Furrow evaluation improves irrigation efficiency.
The Australian Cottongrower 27 (7), 28-33.

Harris G (2006).
Cotton and Grain Water Team Update.
The Australian Cottongrower 27 (6), 12-13.

Harris, G (2006).
Furrow evaluation improves irrigation efficiency.
The Australian Cottongrower 27 (7), 28-33.

Harris, G. (2011).
A decade of change: Water productivity in the cotton industry.
The Australian Cottongrower 31 (7), 20-22.

Hickman M & Collie G (2007).
Cottoning on to training bonus.
Queensland FarmBi$

Hood S & Brotherton E (2007).
A review of siphonless irrigation.
The Australian Cottongrower, 28 (4), 38-43.

Hulugalle N (2006).
Delving deeper into the high yielding crops.
The Australian Cottongrower, 27 (7), 16-2

Hulugalle N & Scott F (2006).
Relative profitability of irrigated cotton rotation systems in NSW.
The Australian Cottongrower. 27 (7), 57-59

Hulugalle N & Weaver T (2010).
Irrigated corn roots can contribute to soil carbon stocks in grey clays.
The Australian Cottongrower, 31 (3), 49-50.

Hulugalle N, Ghosh S, Weaver T, Finlay L, Daniel H & Lockwood P (2008).
Cattle manure and composted gin trash: benefits and costs.
The Australian Cottongrower, 29 (7), 16-17.

Hulugalle N, Tann C, Weaver T & Fitt G (2006).
Permanent beds, soil disturbance and heliothis moth emergence.
The Australian Cottongrower, 27 (4), 49-51.

Hulugalle N & Weaver T (2010).
Reducing greenhouse gas emissions from cotton farming practices.
The Australian Cottongrower, 31, (3), 44-45.

Jackson R (2007).
Undertaking a whole farm water balance.
The Australian Cottongrower, 28 (7) 19-21.

Publications report

Johnson S (2005). Anoda weed- spreading to a field near you? The Australian Cottongrower, 25 (7) 61-64.

Kelly B, Acworth RI, Giambastiani B, Andersen MS, Greve A & McCallum A. (2008).
3D geological models enhance catchment knowledge.
]Australian Landcare Journal 320.

Khan M & Murray A. (2005).
Predator puts bite on green mirid eggs.
The Australian Cottongrower, 26(2), 18

Khan M & Quade A (2006).
Kaolin cons cotton suckers.
The Australian Cottongrower 27(6), 16 – 20.

Khan M & Quade A (2008).
Biology and pictorial identification of mirids.
The Australian Cottongrower, 29(1), 24-27.

Khan M (2009).
Further trial on salt mixture against mirids.
The Australian Cottongrower 30 (4), 37-38.

Knights, S. (2005).
Reducing Evaporation with chemical monolayer technology.
The Australian Cottongrower, 26(3), 32-33.

Knox O, Rochester I, Gupta V & Lawrence L (2006)
Composting in Australian cotton production.
The Australian Cottongrower, 27 (4), 46-48.

Knox O & Gupta V (2007)
Nitrogen and Cotton: a microbial view.
The Australian Cottongrower, 28 (7), 39-41.

Knox O, Nehl D & Gupta V (2007)
Spot the difference? Mycorrhizae in GM and non-GM cotton.
The Australian Cottongrower, 28 (1), 46-49 .

Knox O, Anderson C, Gupta V & Seymour N (2007)
Tiny worms: Nematodes in Australian cotton.
The Australian Cottongrower, 28 (1), 10-15.

Lawrence L & Baker G (2005).
Worming their way into cotton Soils.
The Australian Cottongrower, 26 (2), 19-21.

Lawrence L Tann C & Baker G (2007).
Refuge crops provide refuge for more than Helicoverpa.
The Australian Cottongrower, 28 (1), 26-27.

Lawrence L, Tann C & Baker G (2007).
Refuges harbour pests and beneficial insects.
Farming Ahead 183. 52-54.

Liu G, Gordon S, Yang S & Constable G (2010).
Meeting growing demand for high quality cotton from Chinese mills.
The Australian Cottongrower, 31 (2), 40-43.

Long R & Bange M (2008).
The impact of defoliation timing on fibre quality and textile performance.
The Australian Cottongrower 29 (4), 10-13.

Long R, Bange M, Gordon S, van der Sluijs M & Constable G (2007).
Linking farming systems to fibre quality and textile performance.
The Australian Cottongrower, 28 (1), 28-30.

Long R & van der Sluijs M (2008).
An alternate miniature cotton spinning system.
The Australian Cottongrower, 29 (3), 38-40.

Lu B, Downes SJ, Wilson L, Gregg P, Knight K, Kauter G, McCorkell B (2011)

How do susceptible Helicoverpa s larvae behave on Bollgard II®?

The Australian Cottongrower, 32 (6), 12-15

Lu B, Downes S, Wilson L, Gregg P, Knight K, Kauter G & McCorkell B (2012)

Is the economic threshold for Helicoverpa s larvae in Bollgard II® adequate?

The Australian Cottongrower, 32 (1), 40-45.

Maas S (2007).

Revegetation - by doing nothing, conservation is easy.

The Australian Cottongrower. 28 (4), 11-14.

Maas S, Ludgate Z, Wilson L, DeBarro P, Sequiera R, Murray D & Grundy P (2009).

Silverleaf whitefly - the IPM enforcer.

The Australian Cottongrower, 30 (4), 14-17.

Macfarlane J (2007).

Cotton on to calendar and fact sheets.

Australian Landcare Journal

Mahon R, Downes S, Olsen K & Parker T (2007).

An update on Bt resistance in Helicoverpa.

The Australian Cottongrower, 28 (7), 10-12.

McKenzie D & Batey T (2006).

Recent trends in rapid assessment of soil structure in the field.

The Australian Cottongrower, 27 (1), 58-61.

Mensah R & Austin L (2012).

Using petroleum spray oils (PSOs) to manage aphids and mirids.

The Australian Cottongrower, 32 (7), 49 – 52.

Mensah R, Watts, N & Watts K (2010).

Natural insecticide on the way: Commercialization of a new plant extract in Australia.

Merchandise Magazine , Nov/Dec edition, p. 25.

Mensah R, Vodouhe DS Sanfilippo D.(2008)

A new tool for Africa's organic growers.

Pesticides News 79, 5-7.

Milroy S & Bange M (2006).

Impact of cold shock on early cotton plant development.

The Australian Cottongrower, 27 (3), 33-35.

Montgomery J & Brotherton E (2007).

EM survey for probe placement.

The Australian Cottongrower, 28 (6), 36-37.

Montgomery J & O'Halloran J (2008).

A comparison of water use between solic plant and one-in-one-out skip.

The Australian Cottongrower, 29 (3), 21-25.

Montgomery J & Wigginton D (2007).

Evaluating furrow irrigation performance.

The Australian Cottongrower, 28 (7), 14-18.

O'Halloran J, Rochester I & Dowling C (2005).

New cotton nutrition sampling guidleines.

The Australian Cottongrower. 26 (6), 56-58.

Pendergast L (2009).

I know my dam leaks - but where?

The Australian Cottongrower, 30 (6), 16.

Pendergast L & Hare J (2007).

Capacitance probes - to calibrate or not to calibrate.

The Australian Cottongrower, 28 (6), 34-35.

Publications report

Reynolds M & Jackson R (2008).
Economic benefits of performance evaluation.
The Australian Cottongrower, 29 (3), 26-29.

Reynolds M, Jackson R, Montgomery J & Bray S (2008).
Improving pump installation for efficiency.
The Australian Cottongrower, 29 (3), 29-31.

Richards D, Bange M Linsley D & Johnson S (2007).
2006-2007 seasonal climate analysis.
The Australian Cottongrower, 28 (3), 12-16.

Richards D (2006).
Cotton Awards finalists announced.
The Australian Cottongrower, 27 (3), 32 .

Richards D (2007).
Irrigation trials target improved efficiency on the Downs.
The Australian Cottongrower, 27 (7), 34-35.

Richards D & Bange M (2006).
2005-06 seasonal climate review.
The Australian Cottongrower 27 (3), 8-15.

Richards D, Bange M, Linsley D & Johnston S (2007).
Seasonal climate analysis 2006-07.
The Australian Cottongrower, 28 (3), 12-16.

Richards D & Bange M (2005).
Warm and dry: a perfect recipe for high (irrigated) cotton yields.
The Australian Cottongrower, 26 (3), 12-15.

Richards D (2005).
Whats happening in water research this season?
The Australian Cottongrower, 26 (1), 48-53.

Richards D & Murray A (2006).
Optimising on-farm irrigation: 2005-06 trials.
The Australian Cottongrower, 27 (2), 48-52.

Robson A & Medway J (2009).
Remote sensing applications for cotton.
The Australian Cottongrower, 30 (4), 40-43.

Roche R, Bange M, Vaessen S, Hely T & Mitchell M (2006)
Which cotton row spacing is the better option for southern NSW?
IREC Farmers' Newsletter, No. 173 pp 17-19. http://www.irec.org.au/farmer_f/pdf_173/Cotton%20row%20spacings%20in%20southern%20NSW.pdf

Roche R, Brown E, Bange M, Caton J & Milroy S (2005).
Using Pix on UNR Cotton.
The Australian Cottongrower, 26 (4), 53-55.

Rochester I & Filmer M (2007).
Benchmarks identified for nitrogen efficiencies.
Farning Ahead 190, 52-55.

Rochester I (2006).
Efficient use of Nitrogen fertilisers.
The Australian Cottongrower. 27 (7),48-50.

Rochester I (2011).
Rotating towards carbon-neutral cotton crops.
The Australian Cottongrower, 32 (5), 99

Rochester.I (2011).
Sequestering carbon in irrigated cotton soils.
The Australian Cottongrower 31 (7), 10-14.

Rochester I, Constable G & Dowling C (2005).
Understanding Bollgard II nutrition.
The Australian Cottongrower. 26 (7), 14-16.

Rochester I & Constable G (2006).
Nutrients removed in high-yielding cotton crops.
The Australian Cottongrower, 27 (3), 24-28.

Rochester I, O'Halloran J, Maas S, Sands D & Brotherton E (2007).
Monitoring nitrogen use efficiency in your region.
The Australian Cottongrower, 28 (4), 22-26.

Rossiter L, Murray D, Downes S, Miles M, Wilson L & Kauter G (2007).
Better pupae busting decisions in sprayed conventional cotton.
The Australian Cottongrower, 28 (6), 21-22.

Roth G (2007).
Bat boxes enhance cotton farm environment.
Australian Landcare Jounal

Schmidt E (2008).
The potential for monolayers to reduce the evaporation of water from large storages.
Agricultural Water Management 95, 4 .

Scott F & Hulugalle N (2007).
Rotations and permanent beds to fight the cotton cost-price squeeze.
The Australian Cottongrower, 28 (2), 41-45.

Smith P (2008).
How to evaluate the performance of CP&LM systems.
The Australian Cottongrower 29, (1), 14-16.

Smith P (2008).
How to make sense of pump curves.
Irrigation Australia Journal. 24 (Autumn 2008), 16-17.

Smith P (2007).
Seepage - what can you do about it?
The Australian Cottongrower, 28 (6), 38-39.

Smith P (2007).
Towards better storage management.
The Australian Cottongrower, 28 (2), 21-22.

Smith, P (2008).
Why should you evaluate your CP&LM Systems? - A case study for test results.
The Australian Cottongrower, 29 (1), 17-18.

Smith P, Hare J & White S (2008).
Variety and irrigation strategy: resultd from a darling downs trial.
The Australian Cottongrower, 28 (7), 22-25

Smith P & Jackson R (2008).
Undertaking a whole farm water balance.
The Australian Cottongrower, 28 (7), 19-21

Smith P & Montgomery J (2007).
Case Study - Using EM Surveys for probe Placement.
The Australian Cottongrower, 28 (6), 36-37

Smith P, Montgomery J & Wigginton D (2008).
Evaluating furrow irrigation performance.
The Australian Cotton Grower, 28 (7), 14-18

Smith P, Pendergast L & Hare J (2007).
Capacitance Probes- to calibrate or not to calibrate?
The Australian Cottongrower, 28 (6), 34-35

Smith P & Wigginton D (2008).
Fundamentals of evaluating furrow irrigation.
The Australian Cottongrower, 28 (7), 14-18

Publications report

Smith, P. and Wigginton, D. (2007).
Solutions for Storage Evaporation Control.
The Australian Cottongrower, 28 (2), 19-20

Smith P & Wigginton D (2008).
The value of storage surveys - could you live with a 22pc error?
The Australian Cottongrower, 29 (2), 38-40.

Smith P & Wigginton D (2007).
Want a bigger farm? Buy it with furrow optimisation.
The Australian Cottongrower, 28 (3), 18

Smith P & Wigginton D (2007).
What's been happening to reduce evaporation losses?
The Australian Cottongrower, 28 (2), 16-18

Smith P & Wigginton D (2007).
WUE: Valuable learning curve for experienced irrigator.
The Australian Cottongrower, 28 (3), 21-22

Smith P & Wigginton D (2007).
Positively easy centre pivot and lateral move management.
The Australian Cottongrower,.28 (2), 21-22

Smith R & Gillies M (2009).
Head ditch hydraulics and the variability of furrow inflows.
Irrigation & Drainage, published on-line doi 10.1002/ird.495.

Spanswick S & Truman G (2005).
Using EMI in farm planning and management.
The Australian Cottongrower 26 (3), 24-26.

Squires H (2007).
Dam seepage losses reduced with electronmagnetic technology.
Australian Landcare Journal.

Threlfall C, Deutscher S, Wilson,L & Staines T (2005)
Sweeping up mirids gives a net improvement.
The Australian Cottongrower 26 (7), 55-57

Taylor I (2005).
Fallow Weed spraying- minimising spray drift.
The Australian Cottongrower, 25 (7), 20-22.

Van der Sluijs M & Gordon S (2010).
The cotton spinning industry.
The Australian Cottongrower, 31 (1), 3-36.

Van der Sluijs M (2007).
Contamination in Australian cotton.
The Australian Cottongrower. 28 (2), 3.

Van der Sluijs M (2007).
Contamination in Australian cotton.
Textile Asia. 38 (7), 4.

Van der Sluijs M (2006).
Towards standardised classing in Australia.
The Australian Cottongrower. 26 (7), 50-54

Van der Sluijs M (2008).
Vigilance will ensure cotton remains contaminant-free.
Farming Ahead 199, 58-60.

Van der Sluijs M, Gordon S & Long R (2008).
A spinner's perspective on fibre fineness and maturity.
The Australian Cottongrower 29 (1), 30-32.

Walker S (2006).
he (flea)bane of reduced tillage systems.
Australian Grain November - December 2006.

Walker S & Wu H. (2006).
Knocking out flaxleaf fleabane.
Australian Grain July-August 2006.

Werth J (2009).
New tools in the fight against fleabane.
The Australian Cottongrower, 30 (6), 26.

Werth J, Widderick M & Walker S (2008).
Double knock - a winner for summer weed control.
Future Grain.

Whitehouse M (2006).
Spraying for mirids and benchmarking the triggers-2006.
The Australian Cottongrower. 27 (4), 17-19.

Wigginton D (2009).
Determining storage losses - a key to effective decision making.
The Australian Cottongrower, 30 (4), 12.

Wigginton D (2008).
Evaluating surface irrigation performance.
The Australian Cottongrower, 29 (1), 18-21.

Wigginton D (2006).
Irrigation Siphons - What Does Size Have to do With It?
The Australian Cottongrower, 27 (6),8-10.

Wigginton D (2007).
Numbers prove Rob's efficiency push.
The Australian Cottongrower, 28 (3), 20.

Wigginton D (2006).
Variable application of irrigation water.
The Australian Cottongrower 27 (7), 23-27.

Wigginton, D. (2007).
Want a bigger farm? Buy it with furrow optimisation.
The Australian Cottongrower, 28 (6),18.

Wigginton D (2011).
A journey to reduce seepage loss.
The Australian Cottongrower, 31 (7): 25.

Wild K & Osten V (2008).
Fleabane could become the bane of farming.
Cropping Central 38

Williams D & Montgomery J (2008).
Standardising cotton industry water use efficiency benchmarks.
The Australian Cottongrower, 29 (7), 18-26.

Williams E, Rochester I & Constable G (2005).
Using legumes to maximise profits in cotton systems.
The Australian Cottongrower 26 (6), 43-46.

Wilson L, Heimoana S, Farrell T & Smith T (2008)
Setting thresholds for aphids in cotton.
The Australian Cottongrower, 29 (6), 12-16

Publications report

Non-refereed conference presentations

Al-Jaaidi S, Katz, M, Backhouse D & Pereg-Gerk L (2005)

Transformation of Thielaviopsis basicola: A tool to study the host-pathogen interaction at the molecular level.

FUSCOM Workshop, 1-2 June, Narrabri, Australia.

Al-Jaaidi S, Katz M, Backhouse D & Pereg Gerk, L (2004)

Transformation of Thielaviopsis basicola: A tool to study the host-pathogen interaction at the molecular level.

Genetic Society of Australia 51st Annual Conference, 11-14 July, Melbourne, Australia.

Allen SJ, Anderson CM & Wang B. (2008).

Cotton disease trends & research update on impacts of soil properties on Fusarium wilt.

14th Australian Cotton Conference, 11-14 August 2008, Broadbeach Australia.

Anderson CMT, McGee PA, Nehl DB & Mensah RK (2006).

Lecanicillium lecanii colonises cotton and the cotton aphid.

International Mycology Congress, Cairns, Queensland, Australia, 21-25 August 2006.

Anderson CM, Knox OG, Nehl DB & Allen SJ. (2008).

First record of the spiral nematode Helicotylenchus dihystera infecting cotton roots in Australia.

14th Australian Cotton Conference, 11-14 August 2008, Broadbeach, Australia.

Anderson CM & Lonergan PA (2008).

Seedling disease - getting to the root of the problem.

14th Australian Cotton Conference, 11-14 August 2008, Broadbeach, Australia.

Anderson C, Knox O, Nehl D & Allen S. (2005).

First record of the root lesion nematode Helicotylenchus dihystera in cotton in Australia.

Australasion Plant Pathology Society Conference, 26-29 September, Geelong, Victoria, Australia.

Andersen MS & Acworth RI (2006).

Preliminary investigations of surface water and groundwater interaction in the Maules Creek Catchment, Namoi River, NSW, Australia.

2nd Hydrogeology Research Conference, 13-15 December 2006.

Andersen MS & Acworth RI (2007).

Hydrochemical investigations of surface water groundwater interactions in a sub-catchment in the Namoi Valley, NSW, Australia..

International Association of Hydrogeologists Congress, 17-21 September, Ribeiro, Lisbon, Portugal.

Andersen MS, McCallum AM, Meredith KT & Acworth RI (2009).

Investigation of surfacewater/groundwater interactions using environmental isotopes (2H, 18O, 14C and 3H) in the Maules Creek Catchment, NSW, Australia.

10th Australasian Environmental Isotope Conference & 3rd Australasian Hydrogeology Research Conference 1-3 December 2009, Perth, WA.

Andersen MS (2010).

Geochemical and water quality Implications of changing dynamics in surface water groundwater Interactions. Australian Earth Sciences Convention (AESC) 2010.

4-8 July Canberra, Australia.

Andersen MS, Meredith K, Timms W & Acworth RI (2010).

Investigation of δ18O and δ2H in the Namoi River catchment – surface water/groundwater interactions.

15th Australian Cotton Conference, 10-12 August, Broadbeach Australia.

Andersen MS, Serov P, Berhane D & Acworth RI (2010).

Linking Hyporheic Zone Water Chemistry and Streambed Ecology to Groundwater Discharge and Recharge, Maules Creek, NSW, Australia.

15th Australian Cotton Conference, 10-12 August, Broadbeach, Australia.

Andersen MS, Rau GC, McCallum AM & Acworth RI (2010).

On the temporal variability of streambed hydraulic conductivity.

Groundwater 2010 IAH Australia 'the challenge of sustainable management' 31 October – 4 November 2010, Canberra, Australia.

Andersen M.S., Acworth, R.I., Rau, G.C. & McCallum, A.M. (2010).

Investigations of surface water ground-water interactions in a water stressed semi-arid catchment.

Namoi Groundwater Forum, Namoi Catchment Management Authority and Cotton Catchment Communities CRC, 3 December. Tamworth, NSW.

Andersen MS, Rau GC, McCallum AM, Meredith K & Acworth RI (2011).

Groundwater recharge and geochemical processes in a semi-arid losing stream using temperature, isotopes and geochemistry.

11th Australasian Environmental Isotope Conference & 4th Australasian Hydrogeology Research Conference 12-14 July, Cairns, QLD.

Andersen MS, Meredith K, Timms W & Acworth RI (2011):

Investigation of δ18O and δ2H in the Namoi River catchment – surface water/groundwater interactions.

NSW IAH Symposium 2011 - Uncertainty in Hydrogeology, 5-6 September, Sydney.

Badenhop A, Timms WA, Kelly BFJ, Witts B, Rayner D & Mehrabi S (2011)

Are groundwater salinity changes in the Namoi catchment leading to the degradation of beneficial uses?

NSW IAH Symposium 2011 - Uncertainty in Hydrogeology,4-5 September, Sydney, Australia.

Bahar H, Stanley J, Gregg P & Del Socorro A (2009).

Do green lacewings (Mallada signata) add mortality of Helicoverpa armigera on transgenic Bt cotton?

Entomological Societies of Canada & Manitoba, 18-21 October, Winnipeg, Canada.

Bahar H, Stanley J, Gregg P & Del Socorro A (2010).

Comparing the foraging behaviour of green lacewing larvae (Mallada signata) on transgenic Bt cotton and conventional cotton using Helicoverpa armigera eggs or neonate larvae and cotton aphids (Aphis gossypii) as prey.

59th New Zealand Entomological Soceity Annual Conference, 12-14 April, Wellington, New Zealand.

Bahar H, Mensah RK, Backhouse D, Stanley J, Gregg P & del Socorro A (2011).

Interactions among an entomopathogenic fungus, an insect predator, Mallada signatus (Neuroptera: Chrysopidae), and the host, Helicoverpa armigera on Bt cotton.

Entomological Society of America NCB Annual Meeting, 13-16 March, Minneapolis, USA.

Publications report

Bahar H, Mensah RK, Backhouse D, Stanley J, Gregg P & del Socorro A (2011).

Integration of biological control and microbial control with transgenic Bt cotton.

Entomological Society of America NCB Annual Meeting, 12-15 December, San Diego, USA

Baker GH & Tann CR (2008).

Mating of Helicoverpa armigera moths in Bollgard II cotton.

14th Australian Cotton Conference, 12-14 August , Broadbeach, Australia.

Bange M & Roche R (2008).

Do sowing rules change for high fruit retention transgenic cotton?

14th Australian Agronomy Conference, 21-25 September 2008, Adelaide, Australia.

Bange M, Long R, Constable G & Gordon S (2009).

Evaluation of In-field monitoring methods to reduce neps (in Australian Cotton).

Beltwide Cotton Conference, 4-8 January, San Antonio, Texas, USA.

Bange M, Milroy S & Roberts G (2005).

Factors influencing crop maturity in the Australian cotton industry.

Beltwide Cotton Conference, 4-7 January, New Orleans, Louisiana, USA.

Bange M & Constable G (2006).

Crop Physiology – Producing a Better Fibre.

13th Australian Cotton Conference, 7-10 August, Broadbeach, Australia.

Bange M & Roche R (2006).

Cotton Crop Management for Better Fibre Quality in Dryland Situations.

13th Australian Cotton Conference, 7-10 August, Broadbeach, Australia.

Bange M & Roche R (2006).

Impact of row configuration on high fruit retention (transgenic) rain-fed cotton systems.

Proceedings of the Australian Agronomy Conference, September 10-14, Perth, Australia.

Bange, M. and Roche, R. (2008).

Do sowing rules change for high fruit retention transgenic cotton?.

Australian Agronomy Conference, 21-25 September, Adelaide, Australia.

Berhane D, Vervoort W & Serov P (2008).

Analysis of groundwater thermographs and hydrographs at different time/spatial scales: headwaters of the Namoi River, NSW.

Water Down Under/ Water Resources Conference, 14-18 April 2008, Adelaide, Australia.

Berney P, Wilson G & Ryder D (2008).

The Impact of flooding and grazing on plant communities in the Gwydir wetlands.

Ecological Society of Australia Conference, 1-5 December, Sydney, Australia.

Berney PJ, Wilson GG & Ryder DS (2007).

Vegetation responses to an environmental flow in the lower Gwydir Wetlands NSW.

Ecological Society of Australia Conference, 25-30 November 2007, Perth.

Berney PJ, Wilson GG & Ryder DS (2009).

A temporal comparison of the influence of flows and grazing on vegetation communities in the Gwydir Wetlands, NSW, Australia.

International Conference on Implementing Environmental Water Allocations, 23-26 february, Port Elizabeth, South Africa.

Bhattarai S, Midmore D & Dhungel J (2010).

Diversifying the application of oxygation to lawn, landscape and large scale agricultural irrigation.

Irrigation Australia Limited Conference, 8 January, Sydney, Australia.

Bidstrup J (2006).

Biotechnology - Responsibilities and Rewards.

13th Australian Cotton Conference, 8-10 August, Brisbane, Australia, 109-114

Biggs A, Silburn DM, Free D & Power E (2006).

The Border Rivers catchment – still fresh as a daisy? – Five years on.

Murray-Darling Groundwater Conference, 18-20 September, Canberra, Australia.

Buchannan S & Triantifalis J (2006).

Wet Roots? - High resolution groundwater mapping for Agricultural and Riverine management.

Riversyposium , 5-6 June 2006, Brisbane, Australia.

Burgis D (2006).

Optimising river flow management for environmental and economic sustainability in the Lower Gwydir River, NSW.

Australian Society of Limnology Annual Conference, 25-29 September, Albury, NSW, Australia.

Burns M (2008).

Catchment-scale risk assessment of agrochemicals in Australia.

5th SETAC World Congress, 3-7 August, Sydney, Australia.
Available Online at: http://www.setac2008.com

Carr C (2007).

Landscape ecology of Trichogramma and other egg parasitoids on the Liverpool Plains and Northern NSW.

Ecological Society of Australia Conference, 25-30 November 2007, Perth.

Carr CM, Reid N, Gunning R, Stanley J, Gurr G & Rossiter L (2008).

Supplementing natural populations of a beneficial wasp egg parasitoid for natural pest control in Northern NSW.

Ecology Society of Australia Conference, 1-5 December, Sydney, Australia.

Chapman V, Mass S & McIntyre G. (2005).

Enhancing natural resource management in the cotton industry through partnerships industry.

Australasia Pacific NRM Extension Network Symposium, 28-29 September Toowoomba, Australia, 7-10.
Available online at http://www.regional.org.au/au/apen/2005/1/index.htm#TopOfPage

Charles G & Taylor I (2008).

Optimising weed management in Rounup Ready/Flex cotton.

Weed Society of Queensland Crop-weed Symposium, 10 September, Dalby, Queensland, Australia.

Charles GW & Taylor IN (2006).

Positioning the second generation of herbicide tolerant cotton varieties – Roundup Ready Flex® and Liberty Link® cottons – into Australian cotton farming systems: opportunities and threats.

15th Australian Weeds Conference, 1-3 September, Adelaide, Australia, 359-362

Charles G & Taylor I (2008).

Managing herbicide resistance in cotton: why is the crop management plan important?

14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Charles G & Taylor I (2008).

Managing Roundup Ready Flex(R) cotton using the critical period for weed control in the 2007/08 season.

14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Publications report

Charles GW & Taylor IN (2006).

Opportunities and threats with Roundup Ready Flex® and Liberty Link® cottons, the next generation of herbicide tolerant cotton varieties.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia, 411-416

Cottee NS, Bange MP, Tan DK & Campbell LC (2006).

Identification of thermotolerance in cotton.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Cottee NS, Bange MP, Tan DK & Campbell LC (2008).

Identifying cotton cultivars for hotter temperatures.

14th Australian Cotton Conference, 12-14 August, Broadbeach, Australia.

Coumans, J.V.F., D. Backhouse, M. Katz and L. Pereg Gerk (2005)

On the road towards a proteome analysis of Thielaviopsis basicola interactions with cotton root.

FUSCOM Workshop, 1-2 June, Narrabri , NSW, Australia.

Coumans JVF, M Adams & L Pereg-Gerk (2006)

Proteomics reveals the adaptation of Thielaviopsis basicola to plants species.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Coumans JVF, Pereg-Gerk L, Aitken EAB, Nehl DB & Harvey JA (2006)

Proteomic and genetic investigation of Thielaviopsis basicola isolates exhibiting different levels of pathogenicity towards cotton (Gossypium hirsutum).

11th Proteomics Symposium, 3-5 June, Lorne, Australia.

Coumans JVF, Adams M & Pereg-Gerk L (2006)

Proteomics reveals the adaptation of Thielaviopsis basicola to plants species.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Crawford M, Odeh IOA & Taylor J (2008).

Fuzzy assessment of soil suitability for wheat production in relation to farm productivity.

Proceedings of the 1st Global Workshop on High Resolution Digital Soil Sensing and Mapping, February 5-8, University of Sydney, Australia.

Cunningham SA, Evans TA, Arthur AD, Schellhorn NA & Bianchi FJJA (2010).

What can insects do to help the farm? Soil Improvement, pollination and pest control. Adapting mixed farms to future environments.

The 25th Annual Conference of The Grassland Society of NSW Inc. , 28-29 July, Dubbo, NSW.

Darbis T, Reeve I, Graham S, Farquharson B & Goddard R (2006).

Co-ordination and Co-regulation: Natural resource management governance in the Australian cotton industry.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Del Socorro A & Gregg P (2010)

Potential role of a new attracticide for resistance management of Helicoverpa s in Bollgard® cotton.

Australian Entomological Society 41st Annual Conference, 26-30 September, Perth, Australia.

Del Socorro AP Lowor S & Gregg PC (2008)

Pheromone trapping for the green mirid Creontiades dilutus.

Australian Entomological Society, 34th Scientific Conference and A.G.M., 28 September-1 October, Orange, NSW, Australia.

Del Socorro A, Gregg,P & Lowor S (2006).

Semiochemicals for green mirids in Australia.

Australian and New Zealand Entomological Societies Conference, 24-27 September, Adelaide, Australia.

Del Socorro AP & Gregg PC (2008)

Semiochemicals for green mirids and Helicoverpa: an update.

Northern Farming Systems IPM Forum, 25-26 June, Toowoomba, Queensland, Australia.

Del Socorro A, Gregg P, Ruberson J & Hawes A (2008).

Field trials of attract-and-kill (Magnet®) on American heliothine and other noctuid pests in cotton.

XXIII International Congress of Entomology, 6-15 July, Durban, South Africa.

Del Socorro A, Gregg P & Hawes A (2009).

Development of an attracticide for heliothine moths: from laboratory bioassay of plants to commercial feild trials.

Fifth Asia-Pacific Conference on Chemical Ecology, 26-30 October, Honolulu, Hawaii. USA.

Dodd K, Guppy C, Lockwood P & Rochester I (2006).

Overcoming the confounding effects of salinity on sodic soil research.

ASSSI-ASPAC National Soils Conference, 3-7 December, Adelaide, Australia.

Dodd K, Guppy C, Lockwood P & Rochester I (2006).

The impact of sodicity on the potassium nutrition of cotton.

13th Australian Cotton Conference, 12-14 September, Broadbeach, Australia.

Dowling C (2006).

Advances in nutrition management.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia, 205-209

Downes S, Mahon R & Olsen K (2006).

Resistance and refuges.

13th Australian Cotton Conference, 8-10 August 2006, Broadbeach, 259-266

Errington M, Campbell L, Tan D & Rochester I (2006).

The efficacy of foliar fertilisers on Bollgard II cotton.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia, 615-619

Errington M Campbell L, Rochester I & Tan D (2009)

Nitrogen allocation in Bollgard II® cotton.

Proceedings XVI International Plant Nutrition Colloquium, 26-30 August, UC Davis, Sacramento, USA. Available online at http://ipnc.ucdavis.edu/index.htm

Farrell T, Hulugalle N & Gett V (2008).

Healthier cotton soils through high input cereal rotations.

14th Australian Cotton Conference, 12-14 August 2008, Broadbeach, Australia.

Foley D, Rowland SJ, Wilson G, Boulton A, Nixon M, Winters P & Mifsud C (2008).

Cage Culture of silver perch Bidyanus bidyanus on cotton farms.

Australasian Aquaculture International Conference and Trade Show, 3-6 August, Brisbane, Australia.

Foley DA, Rowland SJ & Wilson GG (2010).

Cage culture of Silver Perch Bidyanus bidyanus: Performance, welfare and economics.

Australasian Aquaculture Conference, 23-26 May, Hobart, Tasmania, Australia.

Foley J, Wigginton D & Eberhard J (2006).

Optimising overhead irrigation systems.

13th Australian Cotton Conference, 8-10 August 2006, Broadbeach, Australia, 303-310

Publications report

Ford G, Thomson N, Spanswick S, Kauter G & Roth G (2006).

Birds on cotton farms.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Frazier P & Wilson G (2006).

Research to underpin environmental flow decision for northern floodpalin rivers.

13th Australian Cotton Conference , 8-10 August, Broadbeach, Australia.

Giambastiani BMS, Kelly BFJ, & The C (2009)

Time-lapse Analysis of Surface and Ground Water Interactions.

First 3D Hydrogeology Workshop, 31 August - 1 September, Geoscience Australia, Canberra.

Gett V (2008).

Healthier cotton soils through high input cereal rotations.

14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Ghosh S, Lockwood PV, Daniel H & Hulugalle N (2006).

Short-term effects of organic amendments on structural stability and fertility of a NSW grey, cracking clay.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Ghosh S, Lockwood P, Daniel H, Hulugalle N, King K & Kristiansen P (2008).

Soil quality changes and affordability of applying organic amendments to a vertosol from Northwestern NSW, Australia.

Soils 2008 – Soil, The Living Skin of Planet Earth, Joint Conference of Australian and NZ Soil Science Societies, 1-5 December, Palmerston North, New Zealand.

Gilbert RL, Gurr GM, Priest MJ & Nielsen S (2006).

Evaluation of plant disease for control of alligator weed in Australia.

15th Australian Weeds Conference, 24-28 September, Adelaide, Australia, 588-590

Gordon S, Long R, Lucas S & Phair-Sorensen N (2008).

Using Siromat to distinguish fibre maturity related issues in the mill.

Beltwide Cotton Conference, 9-11 January, Atlanta, Georgia, USA.

Gordon S, Long R, Lucas S, Phair-Sorensen N & Bange M (2007).

Measurement of average maturity and maturity distribution statistics by Siromat in cotton fibre subject to differential defoliation timing treatments.

Beltwide Cotton Conference, 9-12 January, New Orleans, USA, 1305-1313.

Gordon SG & Bagshaw KM (2007).

The effects of working elements in the fixed batt saw lint cleaner.

Beltwide Cotton Conferences, 9-11 January, New Orleans , Louisiana, USA.

Gordon SG & Naylor GR (2008).

Cotton fibre linear density and maturity measurement and application.

29th International Bremen Cotton Conference, 2-5 April, Bremen, Germany.

Gregg PC, Del Socorro AP, Hawes AJ & Grundy, PR (2005).

Area-wide effects of a plant volatile-based attract and kill formulation against Helicoverpa armigera and H. punctigera in Australia.

21st Annual Meeting of the International Society of Chemical Ecology, 15-19 July, Washington DC, USA.

Gregg PC, Del Socorro AP, Hawes A & Grundy P (2006).
Area-wide impacts of attract-and-kill formulations for noctuid moth pests based on plant volatiles.
Australian and New Zealand Entomological Societies Conference, 24-27 September, Adelaide, Australia.

Gregg P, Lowor S & Del Socorro A (2006).
Pheromones for mirids.
13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Gregg P & Wilson LJ (2008).
The changing climate for entomology.
14th Australian Cotton Conference, 12-14 August 2008, Broadbeach, Australia.

Gregg P, Del Socorro A & Hawes A (2009)
Development of an attracticide for heliothine moths: Regulatory and commercial considerations.
Fifth Asia-Pacific Conference on Chemical Ecology, 26-30 October, Honolulu,Hawaii, USA.

Gregg P (2010).
Millimeters to kilometers: insect mobility and its consequences for pest management .
ASSAB 2010- Annual conference of the Australasian society for the study of animal behaviour, 6-10 April, Narrabri, Australia.

Gregg P, Del Socorro A & Hawes AJ (2010).
A novel attracticide for female noctuid moths, based on plant volatile compounds.
12th International Congress of Pesticide Chemistery, International Union of Pure and Applied Chemistry, 4-7 July, Melbourne, Australia.

Gregg P, Downes S, Tann C. & Del Socorro A (2010)
Helicoverpa punctigera (native budworm) - a puzzle in ecology and resistance management for transgenic cotton.
Australian Entomological Society 41st Annual Conference, 26-30 September, Perth, Australia.

Gregg P, Del Socorro A & Hawes AJ (2010).
A novel attracticide for female noctuid moths, based on plant volatile compounds.
12th International Congress of Pesticide Chemistery, International Union of Pure and Applied Chemistry , 4-7 July, Melbourne, Australia.

Grundy P, Short S, Hawes A, Zalucki M & Gregg P (2006).
Moth busting for Bt resistance management.
13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia, 525-531

Gunawardena TA, McGarry D, Gardner EA & Stirzaker R (2008).
Managing deep drainage for improved WUE: Solute monitoring and ground water response in the irrigated landscape.
14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Gunawardena TA &McGarry D (2011)
Lateral move Irrigators- Innovative engineering solution for improved water use efficiency – but risk of root zone salt accumulation?
The Society for Engineering in Agriculture (SEAg) 2011 Conference 28–30 September, Surfers Paradise, Australia. 196-200

Publications report

Gunawardena TA, McGarry D & Gardner EA (2010)

Will increased water use efficiency lead to salt accumulation in the root zone? A comparison of adjacent lateral move and furrow irrigation.

Irrigation Australia 2010 National Conference, 8 -10 June, Sydney, Australia, pp 71-72.

Gupta VVSR, Hicks M & Kroker S (2011)

Manipulation of rhizosphere communities through aboveground treatment.

Rhizosphere 3 International Conference 25-30 September, Perth, Australia.

Gupta VVSR, Hicks M & Kasper ML (2006)

Decomposition of cotton residues in Australian soils.

18th World Congress of Soil Science, 9-5 July, Philadelphia, USA.

Gurr GM (2005).

Diversity for pest management : moving beyond a first approximation.

Australian Entomological Society AGM and Scientific Conference, 4-9 December, Canberra, Australia.

Gurr GM, Perovic DJ, Gamez-Virues S & Heimoana V (2009).

Multiple methods deployed to understand the effects of landscape structure and composition.

3rd International Symposium on Biological Control of Arthropods, 8-13 February, Christchurch, New Zealand.

Gurr GM & Wratten SD (2005).

Parasitoid Ecology and biological control: an ecological engineering approach.

IX European Workshop on Insect Parasitoids, 5-9 September, Cardiff, UK.

Gurr GM, Wratten SD & Kehrli P (2005).

Cultural Manipulations to enhance biological control in Australia and New Zealand: progress and prospects.

2nd International Symposium on Biological Control of Arthropods, 12-16 September, Davos, Switzerland.

Guy JA, Mifsud C, Nixon M, Winters P, Foley D & Rowland S (2008).

Strategies for Improved growth in silver perch Bidyanus bidyanus- practical considerations for industry.

Australasian Aquaculture International Conference and Trade Show, 3-6 August, Brisbane, Australia.

Heimoana S, Wilson L, Constable G & Fletcher R (2006).

The effects of aphids on photosynthesis in cotton.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia, 485-490.

Herron GA & Wilson LJ (2006)

Insecticide resistance in cotton aphid and two-spotted spider mite: seasons 2004-2005 and 2005-2006

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Herron GA, McLoon MO & Wilson LJ (2008).

Resistance testing summary for cotton season 2006-07 and 2007-08: cotton aphid Aphis gossypii and two-spotted mite Tetranychus urticae.

14th Australian Cotton Conference, 12-14 August 2008, Broadbeach, Australia.

Herron G & Wilson L (2010).

Aphids: Where to from here?

15th Australia Cotton Conference, 11-13 August 2010, Broadbeach, Australia.

Hickman MA (2006).
Maximising your training efforts: A new way forward for the Australian cotton Industry.
13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Higgerson G, Gordon SG, Phair-Sorensen NL, Lucas SR & Miller S (2009).
The accuracy and precision of the SiroMat Instrument.
Beltwide Cotton Conference, 5-8 January, San Antonio, Texas, USA.

Holden J, Devereux A, Hulugalle N, Fukai S, Terry J & Tan DK (2008).
Irrigated maize in cotton systems.
14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Hood S & Carrigan E (2006).
Evaluating alternative and bankless irrigation systems.
13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Hood S & Carrigan E (2006).
Siphon-less Irrigation.
13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Hulugalle NR & Scott F (2006).
Rotations - maintaining our soil quality and profitability.
13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Khan M, Quade A & Murray D (2006).
Mirid damage assessment in Bollgard II - critical damage stage and action thresholds at different stages in irrigated and raingrown cotton.
13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Khan M, Quade A & Murray D (2006).
Mirid management- effect of salt rate when mixed with reduced rate of chemical.
13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Kahn M, Heimoana S & Wilson LJ (2010).
Understanding pale cotton stainer (PCS) damage to Bollgard® II Cotton.
15th Australian Cotton Conference, 10-12 August, Broadbeach, Australia.

Karanja F (2006).
Modelling the supply of ecosystem services from environmental flows in an agriculture-dominated catchment.
The 10th Australian Environmental Postgraduate Conference. 10-13 December, Macquarie University, Sydney, Australia, 110-117.

Kelly BFJ, Giambastiani B, Larsen J, Ralph T & Baker A (2011)
Neogene climate change and the Impact on the hydrostatigraphy of the Lower Namoi catchment, Australia.
AGU Fall Meeting 2011, 5-9 December, San Francisco, USA.

Kelly BFJ, Andersen M, Timms W, Giambastiani B, McCallum A & Acworth I (2010)
Groundwater in cotton growing regions: Recent Insights and future research.
15th Australian Cotton Conference, 10-12 August, Broadbeach, Australia.

Kelly BFJ, Giambastiani BMS, Timms W & The C (2009)
3D hydrograph analysis for constraining the construction of hydrogeological models.
First 3D Hydrogeology Workshop, 31 August - 1 September, Geoscience Australia, Canberra.

Kelly BFJ & Giambastiani BMS (2009)

The need for better conceptual models of aquifers in the Murray-Darling Basin and the goals of the National Centre for Groundwater Research and Training.

First 3D Hydrogeology Workshop, 31 August - 1 September, Geoscience Australia, Canberra.

Korbel K (2007).

Groundwater fauna in Northern NSW: an unknown domain.

Proceedings of the 46th Australian Society for Limnolofy Congress, 1-12 December, Queenstown, New Zealand.

Knox OGG, Gupta VVSR, Gordon K, Lardner R & Hicks M (2010)

Varietal differences in cotton –microbial properties belowground. The Rovira Rhizosphere Symposium - Celebrating 50 years of Rhizosphere research.

Gupta VVSR, Ryder MM & Radclife J. (eds.), 116, The Crawford fund, Deakin, ACT, Australia

Knox OGG & Gupta VVSR (2008)

Cultivar specific differences in N cycling functional groups in the cotton rhizosphere.

8th European Nitrogen Fixation Conference, 4 September, Ghent University, Belgium, p. 193.

Knox OGG, Gupta VVSR, Gordon K, Lardner R & Hicks M (2008)

Varietal differences in cotton – belowground.

14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Knox OG & Gupta VV (2007).

The potential for 21st Century development of agricultural crops to alter soil microbial diversity and function - Cotton as a case study.

Anuual Meeting of the Australian Society of Microbiological, August, Adelaide, Australia.

Koech RK, Gillies MH & Smith RJ (2010).

Simulation modelling in surface irrigation systems.

Southern Region Engineering Conference, 10-12 November, Toowoomba, Queensland, Australia, p. 8

Koech RK, Smith RJ & Gillies MH (2010).

Automation and control in surface irrigation systems: Current status and expected future trends.

Southern Region Engineering Conference, 10-12 November, Toowoomba, Queensland, Australia, p. 7

Long R, Gordon S, Bange M, van der Sluijs R & Naylor G (2006).

Linking farming systems to fibre quality and textile performance.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Long R (2008).

Assessing the impact of harvest aid timing on fibre quality and textile performance.

Beltwide Cotton Conference, 9-11 January, Nashville, Tennessee, USA Available Online at: http://www.cotton.org/beltwide/

Long R, Bange M & Gordon S (2008).

Assessing the impact of harvest aid timing on fibre quality and textile performance.

Beltwide Cotton Conference, 8-11 January.

Lowor ST, Del Socorro AP & Gregg PC (2005).

Sex pheromones of Creontiades dilutus: Identification and field tests.

21st Annual Conference of the International Society of Chemical Ecology, 15-19 July, Washington DC, USA.

Lu B, Downes S, Wilson L, Gregg P, Knight K & Kauter G (2010).

Do bollworm larvae show behavioural resistance to dual-toxin Bt-Cotton?

ASSAB 2010 - Annual Conference of the Australasian Society for the Study of Animal Behaviour, 6-10 April, Narrabri, Australia.

Luelf N, Tan D, Hulugalle N, Knox O, Weaver T & Field D (2006).

Root turnover and microbial activity in cotton farming systems

13th Australian Agronomy Conference, 10-14 September, Perth, Australia,

Lutton S (2007).

Comparsion of fish and macroinvertebrate asseblages between on-farm storage dams and natural wetlands in the Border Rivers Catchment, Australia.

46th National Congress for the Australian Society for Limnology, 3-7 December, Queenstown, New Zealand.

McCallum AM, Andersen MS, Meredith KT & Acworth RI (2009):

Investigations of the impact of groundwater abstraction on surface water/groundwater Interactions using carbon-14.

16th AINSE Conference on Nuclear and Complementary Techniques of Analysis, ANSTO, 25-27 November, Sydney, Australia.

McGee P, Saleeba J, Midgley D, Simpson A, Loke S, Whiffen L, Alomari S, Commandeur Z & Cooper E. (2006).

Ecology of microbes in cotton soils.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia, 597-604

McGee P (2006).

Mycorrhiza in alternative production systems.

International COnference on Mycorrhizas (ICOM 5), 21-29 July 2006, Granada, Spain.

McGarry D (2008).

Improved irrigation efficiency through controlling deep drainage, and monitoring solute signatures and groundwater response.

Irrigation Association Australia, 20-22 May, Melbourne, Australia.

McGarry D (2005).

Improved measurement and prediction of deep drainage under irrigated cotton fields in the Condamine – Balonne – McIntyre catchments and likely ground water responses.

Irrigation Asoociation of Australia, 9-12 May, Townsville, Australia.

McGarry, D., Gunawardena, T.A., Gardner, E.A. and Millar, G. (2006).

Deep drainage under irrigated cotton - surface and groundwater implications.

Irrigation Association of Australia National Conference, 9-11 May 2006, Brisbane, QLD, Australia, 83-84

McGarry D, Gunawardena T & Foley J (2010).

Controlling deep drainage for improved WUE and possible links with ground water movement.

15th Australia Cotton Conference, 11-13 August 2010, Broadbeach, Australia.

McGarry D, Gunawardena TA, Gardner EA & Millar (2006)

Deep drainage and irrigation management.

13th Australian Cotton Conference, 8 – 10 August, Broadbeach, Australia.

Publications report

Manandhar R & Odeh IOA (2008).
Land cover classification from remote sensing imagery: Revisiting and evaluating classification accuracy.
Map India 2008 Conference, 6-8 Ferbruary, Greater Noida, India.

Manandhar R & Odeh IOA (2008).
Analyzing land cover change using knowledge-based image classification of bi-temporal Landsat imageries.
Remote Sensing and Photogrammetry Society Annual Conference, September 15-17, University of Exeter, Falmouth, UK.

Mensah RK & Macpherson I (2006).
Attracting and killing Helicoverpa moths on Bollgard cotton crops: A new strategy for managing Helicoverpa s on conventional cotton crops.
13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Mensah, RK & Austin, L (2006).
A new fungal insecticide for managing Creontiades dilutus (green mirids) on Bollgard and conventional cotton crops.
13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Mensah RK & Austin L (2008).
Development of a new fungus for sucking pest management on transgenic and conventional cotton crops.
14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Mensah R, Austin L & Watts N (2008).
Development of a new semiochemical (Plant X extract) for the management of cotton pests.
14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Mensah RK, Vodouhe SD & Sanfilippo D (2008).
Habitat manipulation and supplementary food spray for enhanced pest management in cotton: implications to cotton IPM.
13th International Congress of Entomology Conference, 6-15 July 2008, Durban, South Africa.

Mensah R & Austin L (2008).
Managing Helicoverpa s and Creontiades dilutus on cotton crops: role of entomopathogenic fungus, semiochemicals and trap crops.
13th International Congress of Entomology Conference, 6-15 July, Durban, South Africa.

Mensah RK, Austin L & Anderson S (2010).
Use of fungal insecticide (BC 639) for the control of Creontiades dilutus on cotton crops in Australia.
15th Australian Cotton Conference, 10-12 August, Broadbeach, Australia.

Mensah RK, Austin L & Anderson S (2010).
Use of fungal insecticide (BC 639) for the control of Silverleaf whiteflies on cotton crops in Australia.
15th Australian Cotton Conference 10-12 August, Broadbeach, Australia.

Mensah RK, Young A & Watts N (2010).
Use of a new plant extract (Plant X) for the control of silverleaf whiteflies on cotton crops in Australia.
15th Australian Cotton Conference, 10-12 August, Broadbeach, Australia.

Mensah RK (2010).
Cotton production in Australia: Role of transgenic varieties in cotton farming landscapes.
World Forum Conference, 14-22 August , University of Cambridge, Cambridge, England.

Mensah RK & Austin L. (2008).

Development of A new fungus for sucking pest management on transgenic and conventional cotton crops.

14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Merlhe M, Bishop T & Odeh IOA (2008)

Uncertainty analysis for clay-EMI spatial prediction models.

8th International Conference on Geostatistics for Environmental Applications (GeoEnv '08), 8-10 September, University of Southampton, UK.

Merrick N (2008).

Groundwater policy reform in Australia.

International Conference, International Ground Water Modeling Centre, 18-21 May, Golden, Colorado, USA.

Merrick, N. (2006).

Cox's creek: Coupled surface water and ground water interactins and modelling, for improved flow and sustainable yield estimates

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Midmore DJ, Bhattarai SP, Pendergast L, Dhungel J, Torabi M & Chen M (2009).

Oxygation – capitalising upon the benefits of aerating irrigation water for annual and perennial cropping.

Irrigation and Drainage Conference 2009, 18-21 October, Swan Hill, Victoria, Australia,

Midmore DJ, Bhattarai SP, Pendergast L & Torabi M (2007).

Oxygation: aeration of subsurface drip irrigation water and its advantages for crop production.

Australian National Committee on Irrigation and Drainage Conference - Sharing the water; food, fibre, people and environment., 19-22 August, Bundaberg, Australia.

Montgomery J, Williams D & Montgomery J (2008).

Furrow irrigation systems comparsions and lessons to improve.

14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Moulynox J & Perek-Gerk L (2006).

Potential Bio-control measures for the soil-borne fungal pathogen Thielaviopsis basicola.

13th Australian Cotton Conference, 10-12 August, Broadbeach, Australia.

Moulynox J,.Pereg-Gerk L & Nehl D (2006).

Research summary: Potential bio-control measures for the soil-borne fungal pathogen Thielaviopsis basicola.

CoSERG meeting, September, Sydney, Australia.

Najar-Rodriguez, AJ, Walter GH & Mensah RK (2006).

Factors affecting aphid tolerance to petroleum spray oils.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Najar-Rodriguez AJ, Walter GH & Mensah RK (2005).

Cotton aphids: Can petroleum oils (PSO's) replace toxic insecticides?

7th International Symposium of Aphids, 2-7 October, Fremantle, Australia.

Naylor G, Gordon S, Long R & van der Sluijs M (2008).

The role of long staple upland and pima cotton – opportunities for medium and ELS types.

14th Australian Cotton Conference, 11-14 August, Broadbeach Australia.

Nehl,D & Knox O. (2006).

Soil biology in cotton farming systems.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Publications report

Neilsen JE & Constable G (2006).

Investigation into partial root zone drying in cotton cropping systems.

13th Australian Agronomy Conference, 10-14 September 2006, Perth, Australia.

Neilsen J (2008).

Effect of soil type on cotton plant water stress.

Beltwide Cotton Conference, 8-11 January, Nashville, Tennessee, USA.

Neilsen, J. (2008).

Soil type effects on cotton plant water relations.

Beltwide Cotton Conference, 8-11 January, Nashville, Tennessee, USA.

Nelson MA, Bishop TFA, Odeh IOA & Triantafilis J (2011).

An error budget for different sources of error in digital soil mapping.

Pedometrics 2011, 30 August – 1 September, Trest, Czech Republic.

Nelson MA, Bishop TFA, & Odeh IOA (2011).

What scale is my digital soil map? Scale and uncertainty in digital soil mapping.

Pedometrics 2011, 30 August – 1 September, Trest, Czech Republic .

Nelson M & Odeh IOA (2008).

Creation of digital soil class map using legacy soil data and ancillary information: A genetic Algorithm approach.

SOILS 2008, a Joint National Conference of Australian Soil Science Society Inc. and New Zealand Soil Science Society, December 1-5, Palmerston North, New Zealand.

Nejem J & Merrick N (2008).

Coupled streamflow and groundwater modelling: challenges in analytical approaches.

The 2008 NZHS & MSNZ Joint Annual Conference, 18-20 November, Shantytown/Greymouth, New Zealand.

Odeh IOA (2006).

Taxonomic and functional pedodiversity in relation to landscape variability and land utilization types.

18th World Congress of Soil Science 9-15 July, Philadelphia, USA

Odeh IOA & Odgers N (2006).

Application of logistic-regression and classification trees to prediction of soil classes at a regional scale.

18th World Congress of Soil Science 9-15 July 9-15, Philadelphia, USA.

Odeh IOA, Bishop T & Malone B (2008).

Modelling soil organic carbon dynamics under different crop production systems in northwestern NSW using the ROTHC.

SOILS 2008 Conference, a Joint National Conference of Australian Soil Science Society Inc. and New Zealand Soil Science Society, 1-5 December, Palmerston North, New Zealand.

Odeh IOA & Wheeler I (2008).

Permutations of the steady-state topographic wetness index in relation to observed soil moisture content.

SOILS 2008 Conference, a Joint National Conference of Australian Soil Science Society Inc. and New Zealand Soil Science Society, 1-5 December, Palmerston North, New Zealand.

O'Halloran JM (2006).

Delivering the goods - Extension in the Australian cotton industry.

Beltwide Cotton Conference, 3-6 January, San Antonio, Texas, USA.

Parakrama A, Jones R & Letcher R (2005).

The farm level impacts of water sharing plans in the Namoi Valley: A stochastic dynamic programming analysis.

49th Annual Conference of the Australian Agricultural and Resource Economics Society, 9-11 February, Coffs Habour, NSW, Australia.

Parr E, Jackson R & Montgomery J (2008).

Water use efficiency in NSW the cotton industry - an industry approach.

Irrigation Australia Conference, 21 May, Melbourne, Australia.

Parr EJ, Wigginton D & Smith PA (2008).

Knowledge management in irrigated cotton and grains.

3rd National Water Education Conference, 30 March-2 April, Surfers Paradise, Australia.

Paytas M, Fukai S & Yeates S (2009).

Effect of early water stress on flower bud removal and development of high retention cotton.

InterDrougnt - III Conference, 11-16 October, Shanghai, China.

Pendergast L & Midmore DJ (2006).

Oxygation: Enhanced yields and water use efficiency of aerated SDI cotton on heavy clay.

Irrigation Association of Australia Conference and Exh

Pendergast L & Midmore DJ (2006).

Enhanced yields and water use efficiency of aerated SDI cotton on heavy clay.

13th Australian Cotton Conference, 8-10 August 2006, Broadbeach, Australia.

Pereg L. (2009)

Black root rot: Cotton disease research at the University of New England.

FUSCOM June 2009, Toowoomba, Australia.

Pereg-Gerk, L., M. Katz, D. Backhouse and S. Al-Jaaidi (2004).

Interactions of the soil pathogen Thielaviopsis basicola with plants.

Australian Society for Microbiology Conference, 26 September – 1 October, Sydney, Australia.

Pereg-Gerk, L. (2006).

Research summary: Molecular tools for the study of the cotton fungal pathogen Thielaviopsis basicola.

CoSERG meeting, September, Sydney, Australia.

Pereg-Gerk L, Al-Jaaidi S, Coumans J, Moulynox J, Katz M, Backhouse D & Nehl D (2006).

Molecular factors in pathogen-cotton interactions leading to Black Root Rot and disease control.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Pereg-Gerk L, Al-Jaaidi S & Katz M (2007)

Molecular factors involved in Thielaviopsis basicola-plant interactions.

Genetic Society of Australasia, 26-29 June, Sydney, Australia.

Pereg-Gerk L, Coumans J, Katz M, Backhouse D & Al-Jaaidi S (2007)

Molecular factors involved in Thielaviopsis basicola-plant interactions leading to black root rot.

16th Biennial Australasian Plant Pathology Society Conference - Back to basics: Managing Plant Disease, 23-27 September, Adelaide, Australia.

Pereg-Gerk L, Al-Jaaidi S, Coumans J, Moulynox J, Katz M, Backhouse D & Nehl D (2006)

Molecular factors in pathogen-cotton interactions leading to Black Root Rot and disease control

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Publications report

Pereg L, Coumans J Katz M, Backhouse D, Al-Jaaidi S Ali GM &. Moulynox J (2011)

Thielaviopsis basicola-cotton interactins leading to black root rot.

5th World Cotton Conference, November, Mumbai, India.

Perovic DJ, Gurr GM, Raman A & Nicol HI (2006).

The importance of non-crop habitats for conservation biological control in Australian cotton landscapes.

Australian and New Zealand Entomological Societies' Conference, 24-27 September, Adelaide, Australia.

Perovic DJ, Gurr GM, & Raman A (2008).

Following the movement of arthropods in an agricultural landscape using rubidium labelling.

Australian Entomological Society Conference, 28 September-1 October 2008, Orange, Australia.

Perovic DJ, Raman A & Gurr GM (2008).

Benefits of Australian native vegetation for conservation biological control in cotton.

3rd International Symposium on Biological Control of Arthropods, 8-13 February, Christchurch, New Zealand.

Perovic DJ, Gurr GM, Raman A & Nicol HI (2008).

The importance of landscape complexity for natural enemy activity in Australian cotton crops.

Australia New Zealand Biocontrol Conference, 10-14 February, Sydney, Australia.

Perovic D, Gamez-Virues S, Heimoana,V, Raman A & Gurr GM (2009).

Multiple methods deployed to understand the effects of landscape structure and composition on natural enemies in Australian agricultural systems.

Proceedings of the 3rd International Symposium on Biological Control of Arthropods, 8-13 February, Christchurch, New Zealand.

Perovic DJ, Gurr GM & Raman A (2008).

Assessing the impact of the spatial arrangement of non-crop vegetation in Australian cotton landscapes: incorporating connectivity in spatially specific landscape complexity analysis.

XXIII International Congress of Entomology, 6-12 July 2008, Durban, South Africa.

Powell SJ (2007).

Characterising flood response of wetland vegetation using temporal NDVI profiles.

ASL and NZFSS conference, 3-7 December, Queenstown, New Zealand,

Prodhan MA, Alomari OK, Ly PK, McGee PA & Saleeba JA (2009).

Root system architecture in cotton.

International Plant Phenomics Symposium, 21-24 April, Canberra, Australia.

Rau G, Andersen MS, McCallum AM & Acworth RI (2008):

Field and numerical investigation of surface water groundwater interactions using natural heat as a tracer – deviation from the 1D flow assumption.

Western Pacific AGU meeting, 28 July – 1 August, Cairns, Australia.

Reid N, Karanja F & Thompson D (2006).

Ecosystem services and biodiversity Indicators.

13th Australian Cotton Conference, 8-10 August 2006, Broadbeach , Australia, 127-138

Reddal AA, Sadras VO, Wilson LJ & Gregg PC (2010).

Predicting spider mite (Acari: Tetranychidae) damage to cotton from a knowledge of their behaviour: a lesson in getting it wrong.

ASSAB 2010 - Annual Conference of the Australasian Society for the Study of Animal behaviour, 6-10 April, Narrabri, Australia.

Reddall AA, Sadras VO, Wilson LJ & Gregg PC (2010).

Choosy mites: preference for water stressed and well watered cotton over two seasons and consequent plant damage.

ASSAB 2010 - Annual Conference of the Australasian Society for the Study of Animal Behaviour , 6-10 April, Narrabri, Australia.

Richards D & Yeates S (2006).

Progress in evaluating the moisture stress response of Bollgard II(R) compared with conventional cotton.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Richards D, Yeates S, Roberts J & Gregory R (2006).

Does Bollgard II cotton use more water?.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Robson A & Abbott C (2010).

Assessing remote sensing as an effective tool for predicting yield variability and total yield within the Australian cotton industry.

15th Australian Cotton Conference, 10- 12 August, Broadbeach, Australia.

Robson A & Abbott C (2010).

Remote sensing applications for the Australian cotton industry.

14th Annual Symposium of Precision Agriculture in Australasia. 2-3 September, Albury, NSW, Australia.

Robson A, Wright GW, Bell MJ, Medway J, Hatfield P & Rachaputi RCN (2009).

Practical remote sensing applications for the peanut, sugar cane and cotton farming systems.

13th Annual Symposium on Precision Agriculture in Australia. 10- 11 September, University of New England, Armidale, NSW. Australia.

Roche R, Bange M, Vaessen S, Hely T & Mitchell M (2006).

Which row spacing yields best?

13th Australian Cotton Conference, 8-10 August 2006, Broadbeach, Australia, 649-652.

Roche R & Bange MP (2008).

Impact of row configuration on high fruit retention (transgenic) varieties in high yielding, high-impact cotton systems in Australia.

Beltwide Cotton Conference, 8-11 January, Nashville, Tennessee, USA.

Roche, R. and Bange, M.P. (2008).

Impact of row configuration on high fruit retention (Bt) cultivars in high-yielding, high-input cotton systems in Australia.

Beltwide Cotton Conferences, 8-11 January, Nashville, Tennessee, USA.

Rochester I, Duggan B & Constable G (2006).

Relationship between phosphorus on Bollgard II Cotton.

13th Australian Cotton Conference, 8-10 August 2006, Broadbeach, Australia, 611-619.

Rochester IJ (2006).

Soil fertility managment and cotton nutrition.

13th Australian Cotton Conference, 8-10 August 2006, Broadbeach, Australia.

Rochester I & Gupta VVSR (2006)

Soil health: a soil ecology perspective.

13th Australian Cotton Conference, 8-10 August 2006, Broadbeach, Australia, 591-596.

Rochester IJ (2008).

Optimizing N fertiliser use and N fertiliser use-efficiency.

14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Publications report

Rochester IJ (2010).

Sequestering carbon in irrigated cotton soils.

15th Australian Cotton Conference, 10-12 August, Broadbeach, Australia.

Roth G (2006).

Cotton Catchment Communities CRC.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Roth GW (2010)

Sustainability indicators for agriculture. A cotton industry case study.

Australian Irrigation Conference, 8-10 June, Sydney Australia.

Roth G and Squires H (2007)

Healthy soils and cotton production. National Healthy Soils Symposium.

3-5 July, Sunshine Coast, Australia.

Roth G & Squires H (2007).

How far has soil health come in the cotton industry ?.

National Healthy Soils Symposium, 3-5 July, Sunshine Coast, Australia.

Rowland S & Allan G (2006).

Development of techniques and evaluation of the potential of cage culture of silver Perch for cotton farms.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia, 661-668.

Rowland S & Allan G (2006).

Aquaculture NSW.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia, 661-668.

Rowland SJ (2010).

Silver Perch Bidyanus bidyanus is still a species with significant potential.

Australasian Aquaculture Conference, 23-26 May, Hobart, Tasmania, Australia.

Seymour N, Knox O & Gupta V (2006).

Understanding soil biology.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Silburn DM, Biggs AJ, Owens JS, Tolmie PE, Foley JL & Cresswell RG (2008).

Salinity in Queensland – hydrologic change from soils to catchments.

2nd International Salinity Forum, Adelaide, 31 March-3 April 2008, Adelaide, Australia. Available Online at: www.internationalsalinityforum.org.au

Simmons AT & Gurr GM (2005).

Increasing atmospheric CO2 and biological control : what is known and what is not.

Australian Entomological Society AGM and Scientific Conference, 4-9 December, Canberra, Australia.

Smith R, Reid N, Duggin J & Roth G (2006).

Biodiversity of tree plantings on cotton farms in the lower Namoi.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Spanswick S (2006).

Land and water best management practice - Challenges and rewards for achieving a profitable environment.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia 147-154.

Stabile MCC, Odeh IOA & McBratney AB (2008).

Application of object-oriented and knowledge-based approach to multi-temporal land use classification using Landsat images.

Proceedings of the 14th Australasian Remote Sensing & Photogrammetry Conference, September 29 - October 3, Darwin, NT, Australia.

Strickland G, Annells A, Addison S & Moulden J (2006).

Refuge crop options for a Bollgard II resistance management strategy at Kununurra, Western Australia.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia, 567-573.

Strickland G, Spafford H & Fairhead J (2006).

Cluster caterpillar survives Bollgard II(R) cotton.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Tann C & Baker G (2008).

Plant host origins of mating Helicoverpa armigera (Lepidoptera: Noctuidae) within Bt cotton crops in ustralia.

International Congress of Entomology, 6-15 July, Durban, South Africa.

Timms WA, Kelly B, Roth I, Badenhop A, Rayner D, & Merhabi S (2010).

Groundwater monitoring, evaluation and grower survey, Namoi catchment.

15th Australian Cotton Conference. 10-12 August, Broadbeach, Australia.

Timms WA, Kelly BFJ, Roth I, Jones P, Witts B, Badenhop A, Rayner D, Mehrabi S (2010).

Evaluating groundwater quality trends, risks of aquifer salinisation and aquifer connectivity, Namoi catchment, Murray-Darling Basin.

Groundwater 2010: The Challenges of sustainable management 31 October -4 November, Canberra, Australia.

Timms W, Kelly BFJ, Blakers R, Farley C, Regmi G, Larsen J & Bowling A (2011)

Implications of 3D geological architecture for surface-groundwater connectivity in the Mooki catchment. NSW IAH Symposium 2011 Hydrogeology in NSW – the Challenge of Uncertainty.

5-6 September, Dockside, Sydney, Australia.

Tann C & Baker G (2010).

Pigeon pea as a suitable refuge crop for use in association with Bollgard II cotton- is it living up to expectations?

15th Australian Cotton Conference, 10-12 August, Broadbeach, Australia.

Trainer E, Minasny B, Field D & McBratney A (2006).

A quick and cost-effective method of estimating potential deep drainage.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Tuck CA, Bange MP, Tan DK & Stiller WN (2008).

Assessing cultivar cold tolerance using germination chill protocols – preliminary studies.

14th Australian Cotton Conference, 12-14 August, Broadbeach, Australia.

Triantafilis J, Buchanan S & Odeh IOA (2006).

Development of a geographic information system to map salinity hazard in the lower Macquarie river valley.

18th World Congress of Soil Science, 9-15 July, Philadelphia, USA.

Tuck CA, Tan DK, Bange MP & Stiller WN (2010).

Cold tolerance screening for cotton cultivars using germination chill protocols.

15th Australian Society of Agronomy Conference, 15-18 November, Lincoln, New Zealand.

Publications report

Vanags C, Vervoort W & Bennett D (2006).

Hydrological behaviour of a Palaeochannel system under irrigation.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia, 383-391.

Vanags C & Vervoort W (2005).

Inverting electromagnetic date to Identify soil hydraulic properties in northern New South Wales.

AGU conference New Orleans, 23-27 May, New Orleans, Louisaiana, USA.

van der Werf W, Landis DA, Gardiner MM, Costamagna AC, Baveco JM, Bianchi FJJA, Schellhorn NA,& Zhang W (2009).

Analysing, forecasting and evaluating the effects of landscape change on the ecosystem service of biological pest control.

Conference on Integrated Assessment of Agriculture and Sustainable Development: Setting the Agenda for Science and Policy. 10-12 March, Egmond aan Zee, The Netherlands.

Vervoort W (2005).

How do sandy Paleochannels affect shallow ground water flow in a clay-dominated vadose zone under flood irrigation?

AGU conference New Orleans, 23-27 May, New Orleans, Louisiana, USA.

Vervort W & van Ogtrop F (2006).

Water resource management and the age of uncertainty: Can science provide any answers?

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Vervoort RW & Vanags CP (2007).

Conceptual models and structure generating algorithms for heterogeneous hydraulic conductivity fields: Impact on simulating groundwater surface water interaction in a palæochannel system.

XXXV IAH Congress Groundwater and Ecosystems, 17-21 September Lisbon, Portugal.

Viscarra-Rossel R (2006).

Soil spectroscopy as a tool for digital soil mapping of cotton soils in Australia.

2nd Global Workshop on Digital Soil Mapping , 4-7 July, Rio de Janeiro , Brazil.

Viscarra-Rossel R (2006).

Robust predications of soil properties with uncertainty by diffuse reflectance spectroscope.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Walker S, Wu H, Osten V, Widderick M & Taylor I (2006).

Managing difficult to control weeds in dryland systems.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Walker S, Werth J, McDonald C & Charles G (2010).

Changes in weeds and practices since the introduction of herbicide tolerant cotton in Australia.

15th Australian Cotton Conference, 10-12 August, Broadbeach, Australia.

Walker S, Thornby D, Werth J & Widderick M (2010).

Glyphosate resistant weeds - the implications for summer crops.

Australian Summer Grains Conference, 17-20 June, Gold Coast, Australia

Wang X, C Tang, C Guppy and PW Sale (2007)

Phosphorus acquisition by cotton, wheat and white lupin under P stress.

Rhisosphere 2 - 2nd International Rhizosphere Conference, 216-31 August, Montpellier, France.

Wang X, Watson L, Guppy CN, Sale PWG & Tang C (2010)

Dynamics and fate of different P sources in three contrasting soil types as determined by P fractionation and isotopic labeling techniques.

4th International Symposium on Phosphorus Dynamics in the Soil-Plant Continuum. 19-23 September, Beijing, China.

Werth J & Thornby D (2010).

Herbicide resistance: prevention is better than cure.

15th Australian Cotton Conference, 10-12 August 2010, Broadbeach, Australia

Werth J, Widderick M, Osten V, Thornby D & Walker S (2008).

Double knock as a tactic for problematic weeds,

14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Werth J, Widderick M, Osten V & Walker S (2008).

Improving glyphosate efficacy of difficult to control summer weeds.

16th Australian Weeds Conference, 18-22 May, Cairns, Australia.

Werth J, Preston C, Roberts G, Taylor I & Baker J (2006).

Glyphosate resistance modelling in Round Ready (R) cotton.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia.

Whitehouse M (2006).

Benchmarking what triggers mirid sprays in cotton the results from the pilot study.

13th Australian Cotton Conference 8-10 August, Broadbeach, Australia.

Whitehouse M & Barnett M (2006).

Intraguild interactions and predator effects: the potential role of Lynx spiders and damsel bugs in the control of green mirid damage in cotton.

11th International Behavioral Ecology Congres, 23-29 July, Tours, France.

Whitehouse M, Khan M, Sequiera R, Maas S & Rudd G (2008).

Organising and presenting the hands-on workshop titled 'Emerging insect pests'.

14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Whitehouse M (2006).

Intraguild interactions and predator effects: the potential role of Lynx spiders and damsel bugs in the control of green mirid damage in cotton.

Australasian Society for the study of Animal Behaviour, 20-23 April, Sydney, Australia.

Whitehouse ME (2007).

Mirid foraging behaviour: understanding fickle mirid damage in cotton.

Australasian Society for the Study of Animal Behaviour, 12-15 April, Canberra, Australia.

Whitehouse ME, Wilson LJ, Downes S, Cave L & Norman P. (2008).

Does transgenic Bt-cotton affect spider mite abundance?

Australasian Society for the study of Animal Behaviour, 27-30 March, Coffs Harbour, NSW, Australia.

Publications report

Whitehouse ME (2007).

Spiders in Australian cotton: Community structure and pest control in the transgenic era.

XVII International Congress of Arachnology, 5-10 August, Sao Pedro, Brazil.

Wigginton D & Smith P (2008).

Building capacity for delivery of commercial irrigation services: A case study in the cotton and grains industries.

Irrigation Australia Conference, 20-22 May, Melbourne, Australia.

Wigginton DW (2010).

Seepage solutions workshop.

15th Australian Cotton Conference, 10-12 August 2010, Broadbeach, Australia.

Williams D & Montgomery J (2008).

Bales per megalitre - An industry wide evaluation of the 2006-2007 season.

14th Australian Cotton Conference, 11-14 August, Broadbeach, Australia.

Wilson G & Ryder D (2007).

Understanding vegetation dynamics under a modified hydrologic regime in the Lower Gwydir wetlands.

Ecological Society of Australia Conference, 25-30 November, Perth, Australia.

Wilson GG, Spencer JA & Heagney E (2008)

Responses of fish and waterbirds to flow variability in the Gwydir wetlands.

Conference on Ecological Response modelling in the Murray-Darling Basin, November, Olympic Park, Sydney, Australia.

Wilson GG & Berney PJ (2009)

Delivering multi-objective environmental flows into terminal floodplain wetlands, northern Murray-Darling Basin, Australia.

International Conference on Implementing Environmental Water Allocations, Port Elizabeth, South Africa.

Wilson GG, Bickel T & Sisson J (2010)

Floodplain fish assemblages and flow-pulse responses in a regulated dryland river system, northern Murray-Darling Basin, Australia.

International Flood Pulse Symposium, February, Maun, Botswana.

Wilson L, Hickman M & Deutscher S (2006).

Research update on IPM and secondary pests.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia, 249-258.

Wilson L & Smith T (2010)

Green Vegetable Bug in cotton regions: gaining a better understanding.

15th Australian Cotton Conference, 10-12 August, Broadbeach, Australia.

Wilson LJ (2008)

IPM in Bt-cotton: Australia as a case study.

International Congress of Entomology, July, Durban, South Africa.

Wilson, L., Hickman, M. and Deutscher, S. (2006)

Research update on IPM and secondary pests.

13th Australian Cotton Conference, 8-10 August, Broadbeach, Australia, pp 249-258

Wilson L (2010).

Is late season damage worth worrying about

15th Australian Cotton Conference, 10-12 August, Broadbeach, Australia.

Wilson L & Smith T (2010).

Green Vegetable Bug in cotton regions: gaining a better understanding.

15th Australian Cotton Conference, 10-12 August, Broadbeach, Australia.

Yang S, Gordon S & Wu L (2011).

CottonSpec – a cotton fiber and yarn quality management tool.

Beltwide Cotton Conference 4-7 January 2011, Atlanta, Georgia, USA, 1486-1494

Yuchun J, Vervoort W & Bishop TF (2009).

Spatiotemporal model of monthly rainfall in the Cox's Creek catchment.

H2009 32nd Hydrology and Water Resources Symposium, 30 November-3 December, Newcastle, Australia.

Yu-Ting Lee L, Ancev T & Vervoort W (2005).

Environmental and economic impacts of water scarcity and market reform on the Mooki.

Ninth Annual Environmental Research COnference, 29 November-2 December 2005, Hobart, Australia, 39-49.

Yu-Ting Lee L, Ancev T & Vervoort W (2007).

Modelling grower response towards end-of valley salinity targets.

51st Annual Conference of the Australian Agricultural and Resource Economics Society, 12-16 February, Queenstown, New Zealand.

Publications report

Industry Reports and other publications

Australian Cotton Extension Network (2006).

Cotton Pest Management Guide 2006-07.

NSW DPI, Orange.

Australian Cotton Extension Network (2007).

Cotton Pest Management Guide 2007-08. NSW DPI, Orange.

Australian Cotton Extension Network (2008). Cotton Pest Management Guide 2011-12. NSW DPI, Orange.

Australian Cotton Industry Development & Delivery Team (2009).

Cotton Pest Management Guide 2009-10.

Cotton Catchment Communities CRC, Narrabri.

Australian Cotton Industry Development & Delivery Team (2010).

Cotton Pest Management Guide 2010-11.

Cotton Catchment Communities CRC, Narrabri.

Australian Cotton Industry Development & Delivery Team (2011).

Cotton Pest Management Guide 2011-12.

Cotton Catchment Communities CRC, Narrabri.

Australian Cotton Industry Development & Delivery Team (2010).

Australian Cotton Production Manual 2010.

Cotton Catchment Communities CRC, Narrabri.

Australian Cotton Industry Development & Delivery Team (2011).

Australian Cotton Production Manual 2010.

Cotton Catchment Communities CRC, Narrabri.

Brodrick R & Bange M (2010)

Overview of recent research into ultra-narrow row cotton in Australia

CSIRO Plant Industry, Canberra 8

Brodrick R & Bange M (2010)

Overview of recent research into ultra-narrow row cotton in Australia, CSIRO Plant Industry, Canberra

8pp http://www.csiro.au/Portals/Publications/Brochures--Fact-Sheets/~/media/CSIROau/Divisions/CSIRO%20Plant%20Industry/UNRcotton_PI_pdf%20Standard.pdf

Ford. F, Thompson, N (2006)

Birds on cotton farms: a guide to common species and habitate management.

Cotton Catchment Communities CRC, Narrabri.

Freebairn, R & Vogel, S. (Ed.) (2009)

Common plants of grazing pastures on the lower namoi floodplain.

Cotton Catchment Communities CRC, Narrabri.

McHugh AD, Boughton B, Eberhard J, McKeering LM, Robson AR & Raine SR (2008).

Evaluating the relationship between plant based measurements and remotely sensed data for irrigation scheduling of cotton.

National Centre for Engineering in Agriculture Publication 1001574/8, USQ, Toowoomba.

Mensah RK (2010).

Amrasca devastans (Indian Green Jassid) Identification, Biology, behaviour, distribution and damage.

Farm Biosecurity Manual for the Cotton Industry, Plant Health Australia Factsheet, 36-37. Available online at www.planthealthaustralia.com.au

Mensah RK (2010).

Lygus lineolaris (Tarnished plant bug) Identification, Biology, behaviour, distribution and damage.

Farm Biosecurity Manual for the Cotton Industry, Plant Health Australia Factsheet 38-39. Available online at www.planthealthaustralia.com.au

Roth G (2010)

Economic, environmental and social sustainability indicators of the Australian cotton Industry.

Cotton Catchment Communities Cooperative Research Centre / The University of New England, Australia, 121 Available online at http://www.cottoncrc.org.au/communities/Cotton_Info/Publications

Spanswick S, Roth G, Jones P & Drew T (2008)

The impact of drought on a cotton community.

Wee Waa 2004-2007. Occasional Publication Cotton Catchment Communities CRC, Narrabri, NSW.

Roth G (2007)

Towards sustainable and profitable water use in the cotton industry.

Cotton Catchment Communities CRC Narrabri Australia, 11

Timms WA, Badenhop A, Rayner D & Mehrabi S (2009).

Namoi groundwater monitoring and evaluation. Report No. 2 Part A: Results of 2009 groundwater monitoring and recommendations for future best practice monitoring framework. Part B: Groundwater user survey.

UNSW Water Research Laboratory Technical Report 2009/25, Final April 2010.

Timms WA, Badenhop A, & Rayner D (2009).

Namoi groundwater monitoring and evaluation. Report No. 1 Review of Groundwater Information and Monitoring Framework.

UNSW Water Research Laboratory Technical Report 2009/04, March 2009.

Timms W, Anderson D & Wasko C (2008).

Groundwater notes for Cotton Growing Regions.

UNSW Water Research Laboratory Report 232.

Townsend, A. (2009)

Fishes on cotton farms:A guide to native fish and habitat management for north-west NSW.

Cotton Catchment Communities CRC, Narrabri.

Vogel.S, Williams.S & Wilson,L. (2011)

Pest and beneficial in Austrlain cotton landscapes.

Greenmount Press, Toowoomba.

Wilson GG, Bickel TO, Berney PJ & Sisson JL (2009).

Managing environmental flows in an agricultural landscape: the Lower Gwydir floodplain. Final Report to the Australian Government Department of the Environment, Water, Heritage and the Arts.

University of New England, Armidale, New South Wales.

Cotton Catchment Communities CRC