



ECONOMIC, ENVIRONMENTAL AND SOCIAL SUSTAINABILITY INDICATORS OF THE AUSTRALIAN COTTON INDUSTRY

Guy Roth



© Guy Roth 2010

This work is copyright. Apart from any use permitted under the *Copyright Act 1968*, no part may be reproduced by any process without the written permission of Guy Roth.

Disclaimer

This study has been published to assist public knowledge and discussion and to help understand and improve the triple bottom line sustainability of the Australian cotton industry.

The information contained in this publication is based on knowledge and understanding at the time of writing (May 2009). However, because of advances in knowledge and the availability of further information, users are reminded of the need to ensure that information upon which they rely is up to date by checking with the appropriate adviser.

For further information on this publication

Guy Roth
(02) 6792 5340
guyroth@roth.net.au

For further information on research and development aiding triple bottom line sustainability in the Australian cotton industry

www.crdc.com.au
www.cottoncrc.org.au
www.cottonaustralia.com.au

ECONOMIC, ENVIRONMENTAL AND SOCIAL SUSTAINABILITY INDICATORS OF THE AUSTRALIAN COTTON INDUSTRY

Guy Roth

FOREWORD

Background to this publication

This publication was initially a thesis submitted in 2009 as partial fulfilment of the requirements for the degree of Professional Doctorate in Science at The University of New England (UNE), Armidale, in 2009. Its conversion to a publication is undertaken with the financial support of the Cotton Research and Development Corporation and the Cotton Catchment Communities Cooperative Research Centre.

Worldwide demand for food and fibre is increasing to service the needs of a growing population and higher standards of living. At the same time, communities are striving for more sustainable management of natural resources. Agriculture will need to achieve both the demands for increased output of agricultural products and those for sustainability. For this to be possible, it is important for farming industries to measure and understand their current sustainability trends and adapt practices as required.

This study set out to compile data from a wide suite of published and unpublished research and monitoring data sets to provide an overall picture of the sustainability trends of the Australian cotton industry. It should be regarded as the beginning of the journey, rather than the end.

Acknowledgements

I would like to convey a special thanks to my supervisor A/Professor Robin Jessop (University of New England) for his guidance throughout this project. Thank you to everyone at the Cotton Catchment Communities CRC (Cotton CRC) for your help and encouragement. I would like to thank Bruce Pyke at the Cotton Research and Development Corporation, with whom I have shared many discussions on reporting economic, environmental and social attributes related to agriculture. I would like to thank Cotton Australia for making available their data on the Best Management Practices program and for their help with the project. Thanks must go to my wife Ingrid for her encouragement and putting up with the distractions of part time post graduate study.

Guy Roth
2010

ABOUT THE AUTHOR

Guy Roth is a director of Roth Rural & Regional Pty Ltd, undertaking research and development program management and specialised consultancy work for a range of clients, principally in the agricultural and natural resources fields.

Guy was the Chief Executive Officer of the Cotton Catchment Communities Cooperative Research Centre (CRC) for four years. Previously, he worked as a Research Program Manager for the Cotton Research and Development Corporation and as a Lecturer in Rural Science and Natural Resources at The University of New England.

Guy is an honorary Research Associate of the School of Environmental and Rural Science, The University of New England.

EXECUTIVE SUMMARY

Expectations for industries to manage resources in a sustainable manner raise the question of how they can demonstrate their sustainability credentials. This study reviews the question of sustainability monitoring and reporting in relation to the Australian cotton industry. Principals of sustainability reporting in business and agriculture were reviewed. A set of sustainability indicators has been developed and economic, environmental and social data compiled. A specific analysis of the cotton industry's environmental management system, the Cotton Best Management Practices program was completed to investigate its potential to track and report farm management practice change over a 10 year period.

ECONOMIC SUSTAINABILITY

Key economic sustainability indicators include (Chapter 3): production area, yield, quality, gross value, profitability and regional economic activity. Very good economic data is available about the cotton industry, although it is not readily accessible for all stakeholders.

Findings in relation to these indicators are:

- The cotton production area in Australia expanded rapidly during the 1980s and 1990s and peaked in 2001 with a national gross value of production of \$1.9 billion.
- Since 2001, the production area of cotton has fallen in response the water shortages caused by drought.
- During the last 20 years, cotton yields have increased significantly, on average 32.9 kg/lint/ha/year and are the highest of any major cotton producing country in the world and are almost three times the world average.
- Australian cotton is now considered a premium quality product in the world, but still has some quality aspects to further improve.
- Cotton has traditionally been the most profitable crop for the farms where it is grown, producing a gross margin of \$500–\$1000 /ha. Costs are increasing and the net price received has been falling which for the last five years has averaged \$369/bale, which has meant that profitability of cotton has been falling.
- Cotton is a major source of regional economic activity where it is grown and usually generates 30–60% the gross value of all regional agricultural income where it is produced, which makes up 10–30% of the gross regional product. Its indirect impact on local economies is high.

ENVIRONMENTAL SUSTAINABILITY

Key environmental sustainability indicators (Chapter 4) include soil, water, pesticide and transgenic crop trait stewardship, biodiversity and greenhouse emissions. The cotton industry has good data sets available from case studies and research reports for environmental indicators. However, these generally give a 'point in time' picture rather than a long term trend and are rarely industry wide. They are also often associated with the best producers, rather than the "average" producer. There are very few data sets that can be used to track changes over long periods of time. The BMP analysis showed it has great potential for monitoring long term trends, which should be supplemented with some targeted and repeated surveys as needed.

Key findings in relation to environmental indicators include:

- There have been significant improvements in the management of natural resources by the cotton industry, particularly in the last decade.
- A reduction in soil tillage, adoption of controlled traffic systems and the use of permanent bed farming systems, and less raking and burning of stubble has resulted in less soil compaction and improved soil physical structure.
- Nitrogen, phosphorus and potassium fertiliser rates are increasing in response to rising yields and hence greater nutrient removal from individual farms. Higher fertiliser rates do not necessarily mean that high yields are unsustainable. however, the sustainability of current nitrogen practices is questionable.
- Soil carbon levels are low and need to be improved.
- Soil testing is common for fertiliser decisions, but monitoring the long trends of soil test data is not done by the majority of cotton growers. The soil monitoring case study showed that these attributes can be monitored by farmers over long periods.
- Soil borne diseases such as fusarium wilt and black root rot have become significant management issues in some areas where cotton is produced.
- There is strong evidence that growers have improved their water use efficiency by 3–4% per annum, or at least 20% in last decade. There are documented examples of even more significant improvements in one year by selected growers as a result of irrigation system improvements. However, more comprehensive data for the 2008 and 2009 cotton seasons is needed to be certain that these recent individual improvements are taking place industry wide.
- Water quality where cotton has been grown is generally very good, with the exception of a few, specific groundwater bores. There has been very little water quality monitoring on-farms and this issue needs to be addressed.
- Data on biodiversity for cotton farms is lacking..
- Most (at least 70%) of cotton farms have river or creek frontage and the status of the riparian land is another important indicator for the broader catchment sustainability..
- Insecticide (82%) and herbicide (>80%) use has significantly declined as a result of widespread adoption (80–90%) of transgenic cotton varieties.
- Insect resistance to insecticides and transgenic cotton traits is a major sustainability risk for the cotton industry. Since the advent of Bollgard® cotton varieties, resistance to many conventional insecticides has declined. There have been no reports of field failures of Bollgard II® varieties due to resistance, however recent data shows an increase in the frequency of *Cry2Ab* resistance alleles in *Helicoverpa punctigera*, which is being closely monitored.

SOCIAL SUSTAINABILITY

Key social sustainability indicators (Chapter 5) include education levels, demographics, employment, health, community attitudes, social capital, research and development and compliance with the law. There exists reasonable data relating to social indicators. This was an unexpected finding as the gathering of social data is usually considered difficult for sustainability reporting. A major gap is employment data, which is not well quantified either for farms or the local service industries.

Social findings in relation to cotton industry participants include:

- The education qualification levels of the cotton industry are higher than other agricultural industries.
- Many training initiatives are underway in the cotton industry and participation rates vary with courses between 20–80% industry participation.
- The cotton industry is one of the leading employers in most of the places where it is grown. The specific number of people employed by the cotton industry is not clear. The cotton industry generates many permanent and casual jobs, although labour demands are falling. It has traditionally provided some of the best salary packages in agriculture.
- 75% of cotton growers have been working more than 40 hours per week, which is considerably more than the national average. The drought has also significantly reduced employment in the cotton industry by 30–60%.
- The number of cotton farmers has been falling and it is estimated there are now 800 cotton growers in Australia.
- Cotton farmers are younger than other farmers that do not grow cotton. Forty percent (40%) of cotton growers are aged under 35 years old, compared to 26% of other farmers. Most of cotton agronomy consultants were aged between 35 and 49 (65%).
- Overall health of people in the industry is improving. Deaths rates in the cotton industry are very low. Workers compensation claims for accidents have been falling, but so too has the planted cotton area. This will need to be monitored as the planted cotton area increases again in response to better seasonal forecasts.
- The cotton industry has very high levels of social capital and consists of many well supported organisations and networks. The connections across other industries are not as strong.
- There is rising participation in the cotton industry by women.
- The Australian cotton industry has a strong research and development culture.
- The number of breaches environmental laws are not publicly available from Government agencies, but are low and close to zero.

In relation to the broader community (Chapter 5), some findings are:

- The number of complaints received by the NSW EPA has fallen significantly from around 50 per year in 2001 to 3 per year for 2006 and 2007.
- People in cotton communities held a positive opinion of the cotton industry.
- Most people outside the cotton industry have a negative attitude towards the cotton industry and their main concerns were water allocations and pesticide usage.
- Independent attitudinal research showed that community concerns about the cotton industry's chemical use, spray drift and water use had reduced significantly between 1998 and 2004.

The analysis of the Cotton Best Management Practices (BMP) program farm practice audit criteria for the 10 years between 1999 and 2008 shows that it is possible to identify and quantify how cotton growers have implemented changes to a wide range

of their farm management practices (Chapter 6). The analysis showed there was:

- A very high standard of legal compliance on farms between 1999–2008 where the BMP program was adopted.
- The mean BMP ranking for all 47 farm practice criteria from the pesticide application, pesticide storage, integrated pest management, farm design and farm hygiene modules for the 10 years between 1999 and 2008 averaged 1.46 (scale 1–4) and showed a 29% improvement over the decade. It showed a 45% improvement between 1999 and 2006. There was a fall in the mean BMP farm practice standards from 2006 standards in 2007 and 2008 that is attributed to the ongoing drought, which reduced expenditure, action and motivation. Despite the drought the BMP farm practice standards for the five years (2004 – 2008) were on average better than the previous five years (1999–2003).
- The analysis showed the mean BMP ranking for certified audited farms between 2006 and 2008 was 24% better than the pre-certified audited farms. This supports the premise that the extra rigour associated with external audit does lead to additional on-farm improvements in practice.

RECOMMENDED ACTIONS

1. The cotton industry develops a five year sustainability reporting plan.
2. The cotton industry develop a sustainability monitoring and reporting process that includes at a minimum the following indicators:
 - i profitability (gross margin);
 - ii economy (gross value of production and employment);
 - iii water use ;
 - iv water quality ;
 - v pesticide use and technology stewardship (transgenic traits, chemistry resistance);
 - vi soil quality;
 - vii energy, greenhouse and carbon balance;
 - viii regional biodiversity;
 - ix industry demographics;
 - x community attitudes; and
 - xi workplace health and safety.
3. The Cotton BMP farm practice rankings be used to monitor sustainability trends.
4. Cotton Australia establishes a formal stakeholder consultation roundtable that convenes annually to discuss sustainability matters.
5. The cotton industry undertake scenario planning activities to explore key drivers of future change and how it might respond.
6. Cotton Australia produce a social responsibility statement for the cotton industry.
7. The cotton industry formally approach the Queensland and NSW Government agencies to establish what environmental data they may be able to provide and their monitoring intentions for the future.
8. Employment figures need to be better quantified both on farm, in the service industries and the value chain.
9. The Global Reporting Initiative should produce a specific sector supplement for agriculture at the industry level for a region/country.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	iii	Soil structure	31
Recommended actions	iv	Soil salinity	32
1 INTRODUCTION		Soil sodicity	32
Introduction	1	Crop nutrition and fertiliser rates	33
Aims and objectives	1	The use of soil testing	34
Background to topic	1	Greenhouse gas emissions	34
Context, assumptions and limitations of study	1	Crop rotations	35
2 LITERATURE REVIEW		Soil biology	36
Monitoring and reporting the sustainability of agriculture	3	Crop diseases	37
Introduction	3	Soil erosion	38
The concept of sustainability	3	Soil pH or acidity	39
Sustainability and agriculture in Australia	3	Soil Cotton BMP rankings	39
Sustainability reporting and monitoring	4	Precision agriculture	39
Introduction	4	Soil research priorities	39
Benefits and barriers to sustainability reporting	4	Case Study: Long term soil health: A 27-year example	40
The need for indicators	4	Water	43
Economic, environmental and social Indicators – the triple bottom line	6	Introduction	43
The Global Reporting Initiative – an international framework	7	Water Use	43
Sustainability Indicators for Agriculture in Australia	8	Irrigation water use levels and compliance	44
Sustainability indicators for irrigated agriculture	9	Water trading	45
Key impacts of cotton production	10	Cotton crop water use	45
Key stakeholders and needs	12	Irrigation methods	48
Conclusion	14	Groundwater levels	48
3 ECONOMIC INDICATORS OF THE AUSTRALIAN COTTON INDUSTRY		Irrigation scheduling methods	49
Introduction	15	Water quality	49
A brief overview of the Australian cotton industry	15	Salinity	49
Industry organisations	17	Insecticides	49
Cotton production area	17	Herbicides	50
Cotton yields	18	Water quality on-farm monitoring on cotton farms	51
Gross value of cotton production	19	Biodiversity and riparian land	53
Cotton bales produced	20	Introduction	53
Number of cotton growers	20	Biodiversity	53
Contribution of cotton production to local government regions	21	Native vegetation	54
The world cotton scene	21	Land clearing	54
Export destinations of Australian cotton	23	Wildlife	54
Cotton prices	23	Birds	54
Economic returns of cotton production to cotton growers	24	Bats	55
Operating expenses	24	Insects and other invertebrates	55
Operating and net profit	24	Fish	56
Profitability of other crops	26	The riparian zone	56
Land and water values	27	Case Study: Reducing bank slumping and pesticide contamination	57
Economic importance of cotton fibre quality	28	Insect, weeds, pesticide use and pesticide resistance	58
Summary	29	Weeds	58
4 ENVIRONMENTAL INDICATORS OF THE AUSTRALIAN COTTON INDUSTRY		Herbicide use	58
Introduction	31	Insect management	59
Recent soil and farming systems sustainability trends	31	Insecticide resistance	60
		Climate change	61
		Summary	61
		Soils	61
		Water	62

Biodiversity and riparian management	62	Integrated pest management module	91
Insects, weeds, pesticide use and resistance	63	Farm design and management module	93
5 SOCIAL INDICATORS RELATED TO THE AUSTRALIAN COTTON INDUSTRY		Farm hygiene module	94
Education	65	Pre-certification Audits in 2006	95
Highest post school qualification	65	Application of pesticides module	95
University level cotton education participation	66	Storage and handling of pesticides module	95
Qualifications of Crop Consultants Australia organisation membership	67	Integrated pest management module	95
Vocational training in the cotton industry	67	Farm design and management module	95
Employment	67	Farm hygiene module	98
Employment levels	67	Petrochemical storage module	98
Income per week	68	Land and water module	98
Hours worked per week	68	Summary	99
Case Study: The Impact of Drought - A pilot study on Wee Waa	69	7 CONCLUSIONS	
Health	70	Sustainability trends	101
Deaths, accidents and injuries	70	Economic trends	101
Pesticides and human health	71	Environmental trends	101
Demographics of the Australian cotton industry	72	Social trends	102
Grower numbers and distribution	72	Data availability and gaps	102
Age of people in the cotton industry	72	Economic data	103
Gender	72	Environmental data	103
Aboriginal communities	73	Social data	103
Social demographic trends for cotton communities	73	Recommendations for sustainability reporting in the cotton industry	110
Community attitudes	73	8 REFERENCES	113
Social Capital	77		
Research and development	79		
Responsibility and compliance with the law	80		
Number of complaints to the EPA	80		
Fines	80		
Summary	80		
Education	80		
Employment	81		
Health	82		
Demographics	82		
Community attitudes	82		
Social capital	82		
Research and development	82		
Legal compliance and responsibility	82		
6 THE COTTON BEST MANAGEMENT PRACTICES PROGRAM: CHANGES IN FARM PRACTICES			
The Cotton Best Management Practices Program	83		
Overview	83		
The process of the Cotton BMP Program on farms	84		
Auditing of the Cotton BMP Program	84		
Monitoring of Cotton BMP Achievements	84		
An analysis of the Cotton BMP audit data 1999-2008	86		
Materials and methods	86		
Aggregated results for the initial BMP modules	86		
Pesticides application module	87		
Storage and handling of pesticides module	90		

LIST OF TABLES

Table 1	Benefits of sustainability reporting	5	Table 32	Australian Cotton Conference Delegate Numbers	79
Table 2	Barriers to adoption of sustainability reporting	5	Table 33	Internet connection of cotton growers	79
Table 3	Uses of sustainability indicators	6	Table 34	Crop size and research and extension expenditure by Cotton Research and Development Corporation	80
Table 4	Characteristics of good reporting and monitoring of sustainability indicators	6	Table 35	The proportion of cotton growers compliant with Cotton BMP program	85
Table 5	The Global Reporting Initiative Guiding Principles	8	Table 36	The mean pre-certification audit rankings 2006–2008 and the mean certification audit rankings for 2006 and 2007 of all the Cotton BMP modules	95
Table 6:	The SCARM sustainability indicators	8	Table 37	A summary of economic sustainability indicators for the cotton industry	104
Table 7	Possible economic and social indicators for agriculture	9	Table 38	A summary of environmental sustainability indicators for the cotton industry	105
Table 8	Priority information products of the cotton industry	10	Table 39	A summary of social sustainability indicators for the cotton industry	108
Table 9	NSW state wide resource condition targets by 2015	11			
Table 10	Eleven sustainable indicators used by Unilever Ltd	11			
Table 11	Possible economic, environmental and social indicators of sustainability in relation to cotton production in Australia	12			
Table 12	Possible sustainability indicators from a Narrabri workshop in 2006	13			
Table 13:	Characteristics of farms with cotton as the main irrigated activity	16			
Table 14:	A summary of the main seasonal factors for cotton from 1999–2008	16			
Table 15	Number of cotton bales ginned in each NSW cotton region 2000–2008	21			
Table 16	Number of cotton bales ginned in each Qld cotton region and industry total 2000–2008	21			
Table 17	Cotton production contribution to agricultural production in selected Local Government regions	22			
Table 18	Trends in fertiliser use 2001–2007	33			
Table 19	Crop rotations of cotton growers 1997–2007	35			
Table 20	Mean BMP land and water module rankings relevant to soil health 2006–2008	38			
Table 21	Agricultural water consumption in Australia 2000–01 and 2004–05	43			
Table 22	Average surface water use in selected valleys of the Darling Basin	44			
Table 23	A summary of key water use figures in the cotton industry between 1988 and 2007	45			
Table 24	Number and percentage of detections of common pesticides for all samples collected in the Namoi Catchment from 1991-1992 through to 2006-2007	50			
Table 25	Namoi water quality of 10 cotton farms	51			
Table 26	Qualifications of the Cotton Consultants Australia 2007 Membership	67			
Table 27	Accidents types in the Australian cotton industry	71			
Table 28	The proportion of female staff in industry organisations	73			
Table 29	Key social indicator findings of shires where cotton is grown	74			
Table 30	Membership of Cotton Consultants Australia	78			
Table 31	Membership numbers of Wincott	78			

LIST OF FIGURES

Figure 1	Existing and potential cotton regions in Australia	15	Figure 32	Soil surface (0–30 cm) pH (water) levels between 1981 and 2007	41
Figure 2	Area of Australian Cotton harvested 1960–2009	17	Figure 33	Soil carbon levels between 1981 and 2007	41
Figure 3	New South Wales regional cotton planting areas 2000–2009	18	Figure 34	Soil available phosphorus levels (Colwell test) between 1981 and 2007	41
Figure 4	Queensland regional cotton planting areas from 2000–2009	18	Figure 35	Soil potassium levels between 1981 and 2007	41
Figure 5	The rise of cotton lint yields 1960–2007 and some related impact factors	19	Figure 36	Soil electrical conductivity levels between 1981 and 2007	42
Figure 6	Gross value of cotton produced in Australia from 1989–2009	20	Figure 37	Chloride levels between 1981 and 2007	42
Figure 7	Cotton bales ginned in Australia for the last 10 years (1999–2009)	20	Figure 38	Exchangeable sodium % levels between 1981 and 2007	42
Figure 8	The number of cotton growers in Queensland regions from 2001–2007	22	Figure 39	Calcium and magnesium levels between 1981 and 2007	42
Figure 9	The number of cotton growers in NSW regions from 2001–2007	22	Figure 40	Water use by major crops in Australia for 2004–05	43
Figure 10	World production and consumption of cotton	23	Figure 41	Water Use Index comparison	46
Figure 11	Weekly cash price of cotton, 1986–2008	23	Figure 42	Components of the volume balance for (a) best and (b) worst case measured whole farm efficiencies	47
Figure 12	Total income of all growers and top 20% growers of Boyce Cotton benchmarking reports 1989–2006	24	Figure 43	Hydrographs of ground water monitoring bore in the Namoi valley	48
Figure 13	Operating expenses of all growers and top 20% growers of Boyce Cotton benchmarking reports 1989–2006	25	Figure 44	Median electrical conductivity ($\mu\text{S}/\text{cm}$) for three sites (Namoi River at Bugilbone, Mehi River at Bronte and Barwon River at Mungindi) located downstream of major cotton growing areas in each valley from 1991/92 through to 2001/02	49
Figure 14	Operating profit before interest of all growers and top 20% growers of Boyce Cotton benchmarking reports 1989–2006	25	Figure 45	Total endosulfan concentrations in the Namoi Catchment from 1991–1992 to 2006–2007	50
Figure 15	Net profit of all growers and top 20% growers of Boyce Cotton benchmarking reports 1989–2006	25	Figure 46	Water quality from 49 cotton grower's sites at the farming Systems Forum, Narromine December 2002	51
Figure 16	Selected operating costs for cotton production Boyce cotton benchmarking reports 1989–2006	26	Figure 47	Vegetation communities for cotton farms in the Moree Shire (1996)	52–53
Figure 17	Irrigated summer crop gross margins per hectare 2000–2007	26	Figure 48	Total herbicide use and glyphosate herbicide use in Australian cotton fields 1993–2007	58
Figure 18	Irrigated summer crop gross margins per megalitre of water 2000–2007	27	Figure 49	Diuron and trifluralin use in Australian cotton fields 1993–2007	59
Figure 19	The value of a Gwydir valley irrigation river licence (based on 972 ML)	27	Figure 50	Annual quantities of insecticide and acaricide applied to the Australian cotton crop between 1995–96 and 2005–06	60
Figure 20	Capital expenditure on irrigation by irrigated activity for five years to 2002–03 Percentage of farms with greater than \$100,000 expenditure	28	Figure 51	<i>Helicoverpa armigera</i> insecticide resistance frequency trends over time	61
Figure 21	Results from CSIRO survey of world cotton mills on Australian cotton quality	28	Figure 52	Highest post school qualification for ABS cotton growing classification (0162) 1991–2006	65
Figure 22	Improvements in fibre length and strength of Australian cotton 1972–2007	29	Figure 53	Highest post school qualification for the balance of agriculture, excluding ABS cotton growing classification (0162) 1991–2006	65
Figure 23	Distribution of saline subsurface material between 6–12 metres at Bourke	32	Figure 54	Number of cotton industry personnel graduating from the UNE/Cotton CRC Cotton Course	66
Figure 24	The proportions of crop nutrients removed in seed cotton (red) or returned to the soil in leaf and stubble after harvest (green)	33	Figure 55	Occupations of graduates of the UNE / Cotton CRC cotton course 2002–2007	66
Figure 25	The range in nitrogen fertiliser rates on Australian cotton fields between 1980–2009	34	Figure 56	Average weekly earnings for cotton growers	68
Figure 26	Variation of soil organic carbon in the 0–06 m depth with time in irrigated and dryland cotton farms in NSW and Queensland	36	Figure 57	Average weekly earnings for other farmers (excluding cotton growers)	68
Figure 27	Fusarium wilt on cotton farms	37	Figure 58	Hours worked per week by cotton growers	70
Figure 28	Verticillium wilt on Namoi Valley cotton farms 1986–2008	37	Figure 59	Hours worked per week by farmers excluding cotton growers	70
Figure 29	Black root rot incidence on plants, fields and farms	38	Figure 60	Cotton growers working 40 hours/ week between 1991–2006	70
Figure 30	precision agriculture on cotton farms 2006–07	39			
Figure 31	Cotton yield per hectare since soil testing began on Armour, 1980–2007	40			

Figure 61	Workers compensation claims in the cotton industry 1997–2008	71	Figure 82	The mean Cotton BMP audit rankings for all the storage and handling of pesticides farm practice criteria between 1999 and 2008	90
Figure 62	The demographic distribution of business related to cotton production in 2003	72	Figure 83	The mean BMP rankings for storage location, storage building, spill containment, storage ventilation, security, work procedures and emergency procedures on BMP audited cotton farms over 10 years between 1999 and 2008	91
Figure 63	The age of cotton growers in 2001 (ABS classification 0162)	73	Figure 84	The mean BMP rankings for signage, mixing and loading sites and systems, worker safety, equipment maintenance, waste disposal and safe transport on BMP audited cotton farms over 10 years between 1999 and 2008	91
Figure 64	The age of farmers in Australia excluding cotton growers in 2001 (ABS classification 0162)	73	Figure 85	The mean Cotton BMP audit rankings for all the integrated pest management practice criteria between 1999 and 2008	92
Figure 65	A comparison of community concerns in cotton growing regions regarding agricultural chemical use between 1998 and 2004	75	Figure 86	The mean BMP rankings for management for early maturity, monitoring and sampling, beneficial insects, resistance management strategy, host and trap crops and area wide management on BMP audited cotton farms over 10 years between 1999 and 2008	92
Figure 66	A comparison of community concerns in cotton growing regions regarding spray drift between 1998 and 2004	75	Figure 87	The mean Cotton BMP audit rankings for the farm design practice criteria between 1999 and 2008	93
Figure 67	A comparison of community concerns in cotton growing regions regarding high water use between 1998 and 2004	76	Figure 88	The mean BMP rankings for management for erosion and water control, management of storms, erosion and run off control, control and cleanup of runoff and use of buffer zones on BMP audited cotton farms over 10 years between 1999 and 2008	93
Figure 68	An opinion of the effectiveness of four agricultural industries caring for the environment	76	Figure 89	The mean Cotton BMP audit rankings for all farm hygiene practice criteria between 1999 and 2008	94
Figure 69	An opinion on the cotton industry	77	Figure 90	The mean BMP rankings for management for detection and notification of Fusarium wilt, machinery and equipment clean down, management of diseases and weeds and destruction of plants affected by Fusarium wilt on BMP audited cotton farms over 10 years between 1999 and 2008	94
Figure 70	A comparison of cotton growing community opinions on the cotton industry	77	Figure 91	Pre-certification audit rankings for the application of pesticides module in the Cotton BMP program, 2006 and 2007	96
Figure 71	Community views on genetic modification of food and fibre	78	Figure 92	Pre-certification audit rankings for the storage and handling of pesticides module in the Cotton BMP program, 2006 and 2007	96
Figure 72	Web hits of the Cotton CRC web site 2004–2007	79	Figure 93	Pre-certification audit rankings for the integrated pest management module in the Cotton BMP program, 2006 and 2007	97
Figure 73	Staff numbers at the Australian Cotton Research Institute, Narrabri	80	Figure 94	Pre-certification audit rankings for the farm design and management module in the Cotton BMP program, 2006 and 2007	97
Figure 74	Number of complaints received by the NSW EPA 1998–2007	81	Figure 95	Pre-certification audit rankings for the farm hygiene module in the Cotton BMP program, 2006 and 2007	97
Figure 75	The mean Cotton BMP audit rankings for all 47 farm practice criteria between 1999 and 2008 from the pesticide application, pesticide storage, integrated pest management, farm design and farm hygiene modules	87	Figure 96	Pre-certification audit rankings for the petro chemical storage module in the Cotton BMP program, 2006–2008	98
Figure 76	The mean Cotton BMP audit rankings for all application of pesticides module farm practice criteria between 1999 and 2008	87	Figure 97	Pre-certification audit rankings for the land and water module in the Cotton BMP program, 2006–2008	99
Figure 77	The mean BMP rankings for pesticide application management plans and farms maps on BMP audited cotton farms over 10 years between 1999 and 2008	88			
Figure 78	The mean BMP rankings for pre–season contact with neighbours, consultants, applicators and workers on BMP audited cotton farms over 10 years between 1999 and 2008	88			
Figure 79	The mean BMP rankings for in–season communication with neighbours, consultants, applicators on BMP audited cotton farms over 10 years between 1999 and 2008	89			
Figure 80	The mean BMP rankings for worker awareness of applications, determination of weather conditions, monitoring and recording of weather conditions and application of pesticides in appropriate conditions on BMP audited cotton farms over 10 years between 1999 and 2008	89			
Figure 81	The mean BMP rankings for pesticide choice, training of applicators, label directions, equipment choice and calibration and record keeping on BMP audited cotton farms over 10 years between 1999 and 2008	90			

INTRODUCTION

Worldwide demand for food and fibre is increasing to service the needs of a growing population and higher standards of living. At the same time, communities are striving for more sustainable management of natural resources. Agriculture will need to achieve both the demands for increased output of agricultural products and those for sustainability. For this to be possible, it is important for farming industries to measure and understand their current sustainability trends and adapt practices as required.

“Sustainability” is a commonly used word, but its actual meaning is subject to differences in interpretation. This is in part because of discrepancies with short and longer term time frames, the influence that personal values play in the perceptions of sustainability and the challenges managing the trade-offs associated with decisions. For the purpose of this study, sustainability includes three distinct, but related economic, environmental and social parameters.

Farmers manage the majority of Australia’s land and diverted water resources. As a result they have a direct influence on the sustainability of our economy, environment and communities. Cotton farms are intensive large scale cropping systems and the industry is continually under pressure to demonstrate sustainable management practices. Monitoring and benchmarking is essential to measure achievements, identify areas for improvement and communicate trends to interested parties. There is an adage *“if you can’t measure it – you can’t manage it”*.

Measurement of industry sustainability requires consistent approaches across multiple farms, regions and sites, repeated over long periods of time. Despite considerable industry interest, establishing a core set of indicators and gathering the data has been elusive. A core set of indicators needs to be applicable across the range of farming situations, both large and small.

Every farm is unique due to its location, history, natural resources and human components. Cotton farms around the world face many common challenges. These challenges include falling profitability, increasing crop yields, and improving fibre quality. They also include energy use, greenhouse gas emissions, the management of biodiversity, salinity, water use and quality, soil health, interactions with river and groundwater systems, pesticide use and transgenic trait crop management. There are also many external pressures such as climate change and variability, market forces, community views and changes to government policy.

Performance indicators are needed to monitor cotton production systems and report on their trends towards sustainability. Sustainability indicators will also assist with business planning, resource allocation, and provide documented evidence of natural resource stewardship and community impacts. These indicators will need to have attributes that can be applied at the farm, industry, regional or national level.

This study set out to compile data from a wide suite of published and unpublished research and monitoring data sets to provide an overall picture of the sustainability trends of the Australian cotton industry. It should be regarded as the beginning of the journey, rather than the end.

AIMS AND OBJECTIVES

The aim of this study was to investigate the reporting of sustainable development and to collate data for selected economic, environmental and social sustainability indicators of the Australian cotton industry.

The objectives of this study included:

- to review the literature on sustainability indicators in relation to agriculture and specifically cotton production
- to identify, collect and compile data to benchmark selected economic, environmental and social sustainability indicators for the Australian cotton industry including its Best Management Practices Program
- to provide trend analysis of selected indicators over time where possible
- to identify gaps and recommend priorities to improve the future collection of sustainability indicator data.

OUTLINE

Chapter 1 provides an introduction for this study. Chapter 2 reviews the sustainability reporting literature and its relevance to agriculture. Key well known impacts of cotton production are summarised as well as some stakeholder needs on possible sustainability indicators. Possible sustainability indicators for the cotton industry are advanced. Sustainability report data and information is compiled on economic (chapter 3), environmental (chapter 4) and social (chapter 5) indicators relevant to the Australian cotton industry. Chapter 6 completed a 10 year analysis of the Australian Cotton Best Management Practices Program to identify and quantify how cotton growers have changed a range of their farm practices and to see if the farm practice audit rankings can be used to monitor trends. Conclusions and recommended future actions are summarised in Chapter 7.

CONTEXT, ASSUMPTIONS AND LIMITATIONS OF STUDY

This study was completed on a part time basis as part of the requirements of the Professional Doctorate Degree in Science at The University of New England. It was not possible to undertake detailed field experimentation on the many various parameters related to the sustainability of the cotton industry. It was also not possible when working full time to spend time collecting extensive experimental data sets. This project draws information from various published and unpublished reports.

An early observation from this study was the lack of information to support environmental and social outcomes. Therefore, I encouraged and supervised some final year honours students at UNE to undertake pilot studies, where we collected on-farm data for possible environmental indicators such as biodiversity and water quality. There was a large void in social data information. Thus, some raw statistical data was purchased from the Australian Bureau of Statistics. The BMP data for the participating farms is commercial in confidence and information on individual farms cannot be disclosed.

The cotton industry in the context of this study is limited to on-farm production. It does not include the post farm gate supply chain such as cotton gins, which are in Australia, or cotton mills and spinners, which are all based overseas. It also does not include the textile or garment manufacturing industry in Australia.

MONITORING AND REPORTING THE SUSTAINABILITY OF AGRICULTURE

Introduction

Agricultural industries need to demonstrate that their practices are sustainable and communicate this to the community and government. In addition to economic viability, there is growing expectation that business, including farms, be socially and environmentally responsible. Cotton farms around the world face many common challenges. These challenges include falling profitability, increasing crop yields, and improving fibre quality. They also include energy use, greenhouse gas emissions, the management of biodiversity, salinity, water use and quality, soil health, interactions with river and groundwater systems, pesticide use and transgenic trait crop management. There are also many external pressures such as climate change and variability, market forces, and changes to government policy. An important part of this challenge is measuring the sustainability of cotton production systems.

The concept of sustainability

The concept of sustainability is a widely used expression, but its actual meaning and understanding tends to be aligned to the user's purpose, emotional intelligence and values. There are a considerable range of views in what constitutes sustainability and the conundrums of the definition. These have been widely debated (Fricker 1998; Stoneham *et al* 2003; Black 2005; Pretty 2005). It is not the intention of this study to discuss the pros and cons of various formal definitions of sustainability. Sustainability is widely regarded as a journey, not a destination (Scott 2005). Thus, it is more important and pragmatic to understand how farm industries contribute to ecological sustainable development and what practices can be modified to further improve their sustainability performance. It is generally accepted that the sustainability concept has three distinct, but related ecological, economic and social components (Global Reporting Initiative 2002).

The 1980 World Conservation Strategy of the International Union for Conservation of Nature and Natural Resources promoted sustainability as a strategic approach to ensure that development achieved:

- to maintain essential ecological processes and life support systems;
- the preservation of genetic diversity and
- sustainable utilisation of species and ecosystems (IUCNNR 1980).

Internationally, the most agreed definition of sustainability is that of The World Commission on Environment and Development (1987), in what is known as the Brundtland Report, which defined sustainable development:

“as development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

The Brundtland Report led to the 1992 United Nations Conference on the Environment and Development at Rio de Janeiro, which

adopted the Agenda 21 statement (United Nations 1992). This statement provided a commitment by 150 countries to develop policies that will protect the environment and promote sustainable use and management of environmental systems and natural resources. It also recognised that social, economic and ecological processes are interrelated.

The Australian Government subsequently developed its National Strategy for Ecological Sustainable Development (Commonwealth of Australia 1992) and further refined the concept of sustainability to:

“Using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased”

The core objectives of the Australian strategy are:

- to enhance individual and community well being and welfare by following a path of economic development that safeguards the welfare of future generations;
- to provide for equity within and between generations; and
- to protect biological diversity and maintain essential ecological processes and life support systems.

The Australian Government has implemented a number of initiatives to progress ecological sustainable development. These can be found on its internet site; www.environment.gov.au/esd (Department of Environment, Water, Heritage and the Arts 2008). There are five key principles of sustainability: intergenerational equity, intragenerational equity, the precautionary principle, internalisation of environmental costs taking into account improved valuation and incentive mechanisms and the conservation of biodiversity (IGAE 1992).

Sustainability and agriculture in Australia

Given the importance of agriculture as the ultimate provider of food, fibre and shelter for the human population, no sector has a greater role in moving towards development that is sustainable (Smith and McDonald 1998). In Australia, farmers own or lease a large portion of Australia's land and water so it is essential the agricultural sector engages in the sustainability frameworks established by the United Nations and the Australian Government.

The Australian Government Standing Committee on Agriculture (1991) defined sustainable agriculture as: “*the use of farming practices and systems which maintain or enhance: the economic viability of agricultural production: the natural resource base: and other ecosystems which are influenced by agricultural practices*”.

The principles of sustainable agriculture discussed in that report were that:

- farm productivity is enhanced over the long term;
- adverse impacts on the natural resource base and associated ecosystems are ameliorated, minimised or avoided;
- residues resulting from the use of chemicals in agriculture are minimised;
- net social benefit (in both monetary and non monetary terms) from agriculture is maximised; and

- farming systems are sufficiently flexible to manage risks associated with the vagaries of climate and markets.

The Australian Government Department of Agriculture Fisheries and Forestry and its associated Rural Research and Development Corporations all have as part of their strategic and operational plans economic, environmental and social targets and outcomes. Rural Research and Development Corporations need to report against sustainability goals under the Primary Industries and Energy Research and Development Act 1989 (PIERD Act 1989) activities related to ecologically sustainable development.

The Cotton Research and Development Corporation 2003–2008 Strategic Plan, states as their corporate outcome:

“A more sustainable, profitable and competitive cotton industry, providing increased environmental, economic and social benefits to regional communities and the nation”
(Cotton Research and Development Corporation 2003).

Australian cotton growers have also committed to sustainability. Two of the priorities of the Australian Cotton Growers Research Association (ACGRA) included to:

- *improve the sustainability of the cotton industry and its catchments and*
- *improve the profitability of the cotton industry* (ACGRA 2007).

Cotton Australia, which represents cotton grower interests, has a 13-page policy statement on sustainability, which states:

- *Cotton Australia commits to continually improving the value the industry delivers to the environment, to individuals, and communities, and to the economic well being of our nation* (Cotton Australia 2006a).

The Cotton Catchment Communities Cooperative Research Centre also has as one of its core goals in its strategic plan:

“To enable the cotton industry to improve profitability and sustainability of production” (Cotton Catchment Communities CRC 2006).

Therefore, clearly Australian agriculture and the Australian cotton industry have sustainability goals and objectives. The challenge for them is providing the evidence that they are meeting the goals and aspirations of these policy statements by measuring and reporting changes based on some agreed indicators.

On the other hand, many organisations believe that the cotton industry is not sustainable. For example, the World Wildlife Fund (WWF) believes a tremendous amount of work will be required to bring cotton production into line with minimally acceptable environmental standards around the globe (www.panda.org/about_wwf/what_we_do/policy/agriculture_environment/commodities/cotton, accessed 20th January 2009). The Better Cotton Initiative was established by WWF and others to improve environmental and social performance of the global cotton industry (www.bettercotton.org).

Philosophies and aspirations are easy to state, but getting agreement on operational elements of sustainability is a more difficult proposition. In fact, it appears easier to understand, agree and

take action on what is not sustainable, rather than agree on what is a sustainable practice.

SUSTAINABILITY REPORTING AND MONITORING

Introduction

Sustainability reporting is the practice of measuring, disclosing and being accountable for organisational performance towards the goal of sustainable development and is considered synonymous with other terms used to describe for accounting for economic, environmental and social impacts such as triple bottom line or corporate responsibility (Global Reporting Initiative 2006).

While a number of benefits have been proposed for organisations to monitor and report information on performance there are also several risks and barriers inhibiting open disclosure of facts and figures. Sustainability reporting for corporations is voluntary in Australia; however, there is increasing interest in its use (Parliamentary Joint Committee on Corporations and Financial Services 2006). By way of example, the BHP Billiton shareholders pack for 2008 contains high profile material flagging its sustainability report.

Benefits and barriers to sustainability reporting

Table 1 summarises some of the reasons why organisations may undertake sustainability reporting. There are clearly many drivers for organisations to monitor and report the sustainability of their operations which include, improved management, governance, compliance and better communication. These can perhaps be best summed up by the cliché – “you need to measure to manage”.

There are a number of barriers and reasons why organisations have not embraced sustainability reporting. Table 2 summarises the barriers to adoption of sustainability reporting. Cost is considered the major impediment to Australian companies, which could be about \$150,000 per year for a large company (Parliamentary Joint Committee on Corporations and Financial Services 2006).

The need for indicators

Sustainability reporting requires the use of indicators. The United Nations Program for Action for Sustainable Development, as part of the Rio Earth Summit, adopted the Agenda 21 plan for sustainable development, which advocated the development of indicators to measure our progress towards sustainability and acknowledged that economic, ecological and social process are interrelated (United Nations 1992).

The Organisation for Economic Cooperation and Development (OECD) and Commission on Sustainable Development (CSD) have been developing indicators to monitor the performance of countries in relation to the Agenda 21 plan. The Commission on Sustainable Development reports by Australia identify national measures that contribute to Australia’s commitments to the Agenda 21 plan (DEWHA 2008). Australia is a member of the OECD, which also has a program of monitoring member nation’s commitment to sustainable development, which includes the development of environmental, economic and social indicators.

Gallopin (1997) has reviewed various theoretical definitions of indicators and concluded indicators are variables, which are an operational representation of an attribute (quality, characteristic, property) of a system. Most management textbooks include some discussion of performance indicators and the characteristics of them. A common acronym is that they must be SMART: Simple, Measurable, Achievable, Relevant and Timely.

Sustainability indicators are used for a number of purposes as summarised in Table 3, on the following page.

The main features of performance indicators adopted by companies include:

- input measures are the least difficult to develop and hence most common, whereas outcomes measures are rare;
- performance targets are used to varying degrees. Most do not set targets but compare incremental movements over time;
- few companies link social, economic and environmental performance measures

Table 1 Benefits of sustainability reporting

DRIVER OF THE BENEFIT	COMMENT
Cost reductions	More performance information should lead to better management of resources and therefore cost reductions
Market opportunities	When a company can demonstrate their practices are sustainable consumers are prepared to pay a premium in the market. Organic food is one example.
Risk reduction	Corporations Law requires organisations to manage risks such as OH&S, and pollution. Reporting is a core requirement of these management systems.
Sense of community	Doing the right thing and being able to demonstrate it. Negative community reaction can cost corporations' money and expose it to other risks such as government intervention.
Attract further Investment	An example is the growth in socially responsible investment portfolios in investment houses.
Regulatory reporting and corporate governance	Corporations are required to report financial information to ASX, ATO etc. Others have to report environmental reports as part of their development approvals.
Community license to operate	Failure to provide such information leads to suspicion and could lead to a loss of stakeholder support.
Greater shareholder ownership	There are now more small shareholders in public companies that show an interest that their company is doing the right thing.
Self regulation	More self regulation and third party regulation rather than legal requirements
Reputation	Being able to promote their reputation ranking of industry
Employee expectations	Employees like to know how their activities contribute to the business and or community / environment. Reporting makes this transparent.
Management tool	Benchmarking and tracking performance.
Accountability for any public funds	Accountability for any public funds invested directly or indirectly into the organisation or industry
Communication	Internal and external

Source: summarised from various sources including Allens Consulting 2002; Deegan 2001; Global Reporting Initiative 2002, Global Reporting Initiative 2006

Table 2 Barriers to adoption of sustainability reporting

BARRIER TO ADOPTION	COMMENT
Cost	Collecting and managing data is expensive
Determining indicators to monitor	Determining a set of good indicators to monitor and measure is difficult
Sensitivities	It is not all good news
Difficulty in capturing reliable information	Some aspects are very difficult to collect meaningful and repeatable data
Disclosure	Disclosure can create business risks which competitors and regulators may seize upon
Sphere of influence	Difficult to determine the sphere of influence of an organisation
Scale and frequency	Technical issues with data collection
Insufficient resources	Many organisations have good intentions, but simply have not allocated enough resources

Source: summarised from various sources including Allens Consulting 2002; Deegan 2001; Global Reporting Initiative 2002, Global Reporting Initiative 2006

- some companies benchmark against legal limits; and
- leading companies enable data to be disaggregated and customized through web based reporting (Allen Consulting Group 2002).

The International Institute for Sustainable Development Measurement and Indicators Program selected 10 principles for the choice and design of indicators (Hardi 1997). These included; holistic, essential, adequate, practical focus, open, effective communication, broad participation, ongoing assessment, and institutional capacity. Table 4 summarises characteristics of good reporting and monitoring of sustainability indicators.

The spatial dimension of indicators is often overlooked because of limited capacity, skills and cost of obtaining and processing image data (Langaas 1997). Spatial data would be very useful for environmental indicators such as land use change, land condition, vegetation, and some water quality aspects such as

Table 3 Uses of sustainability indicators

USES OF SUSTAINABILITY INDICATORS
Provide baseline information
Accountability
Assess current performance
Assess conditions and trends
Compare data across places and situations
Assess changes in policy or practices
Anticipate future conditions and trends
Help planning
Enable reporting
Source: drawn from various sources including Gallopini 1997; Global Reporting Initiative 2002, Global Reporting Initiative 2006

Table 4 Characteristics of good reporting and monitoring of sustainability indicators

CHARACTERISTICS OF GOOD SUSTAINABILITY INDICATORS
Indicators must be measurable or observable
Data must be available or obtainable
Easy to collect and measure and cost effective
Reliable and unambiguous and free of bias
Related to identifiable policies or actions
Related to impacts of agriculture and not other factors
Indicate movement towards or away from desirable outcome
Interpreted in context of scale and coverage and seasonal changes
Politically acceptable and supported by industry so they are used
Balance of economic, environmental and social
Sensitive to measuring change over time, locations and industries
Amenable to predicting outcomes
Consistent with legislation
Incorporated into day to day management
Source: compiled from Gallopini 1997; NLWRA 2005, Walker 2002

sedimentation. It is also very visual, thus it is easy to understand, and can cover large areas, which is not possible with point samples. The adage “a picture is worth a 1000 words”, could help simplify the comprehension of reports to readers.

Care must also be taken not to monitor and measure too many indicators, while some balance is needed between the economic, environmental and social categories. The geographic sphere of impact needs to be considered as many on-farm actions have impacts that extend beyond the farm boundary.

Climatic variability will have a significant impact on many biophysical attributes and needs to be accounted for in any monitoring program as this influence can mask or accentuate data trends. Farming activities do involve disturbances to the farm environment, however the longer term system resilience to these disturbance events is what is important. The farm system is capable of adjusting to changes and some short term decline for a longer term gain is possible with many actions. Thus, it is important to collect repeated data sets at comparable times to account for any short term changes caused by the climate or a farming practice. Scott (2005) discussed the importance of being able to measure sustainability over decades for Australian farms.

Determining the critical levels of any indicators is challenging. These can either be historical pre farming disturbance, a desired level or target set by the government/community, or a potential critical threshold for a biological process. There are also many technical and practical challenges when using indicators. These include scale, content, boundary, frequency, credibility, data sources, and input versus output indicators.

It has been suggested within the literature that indicators of unsustainability may be used in place of indicators of sustainability (Smith and McDonald 1998). This is because it is easier and quicker to identify constraints to progress rather than all factors that contribute to progress. Examples of unsustainability indicators could include, erosion and sedimentation, declining yields, and increased use of marginal land or poor water quality.

ECONOMIC, ENVIRONMENTAL AND SOCIAL INDICATORS – THE TRIPLE BOTTOM LINE

The term “triple bottom line” reporting was coined by Elkington (1997), to describe performance reporting against economic, social and environmental parameters. It represented departure from previous bottom line perspectives which traditionally focused on financial considerations.

This implies that an organisation must be economically viable, minimizing its impact on the environment and acting in conformity with societal expectations. Indicators of economic growth such as employment and profitability have historically been the major indicators used by regions to reflect success, but increasingly communities want to give greater consideration to the environmental and social implications of any actions.

Elkington (1997) described the triple bottom line at its narrowest as a framework for measuring and reporting corporate performance against economic, social, and environmental parameters. At its broadest, the term is used to capture the whole set of

values, issues and processes that companies must address in order to minimize any harm resulting from their activities and to create economic, social and environmental value (Sustainability 2005).

Smith and McDonald (1998) explain that:

- ecological sustainability requires that development is compatible with ecological processes;
- economic sustainability means it is economically feasible; and
- social sustainability means it is socially acceptable.

Core characteristics of triple bottom line reporting include accepting accountability, transparency, integrated planning, committed to stakeholder engagement, multi dimensional measurement and reporting (Allens Consulting Group 2002).

Pritchard *et al* (2003) conducted a major triple bottom workshop line reporting in rural Australia and concluded there is widespread support of the triple bottom line framework, however there is much uncertainty about the nature of the social dimension and how to integrate the social, environmental and economic outcomes. Researchers and policy makers have mixed and dissenting views on the question of social indicators. The choice of social indicators is challenging and there is a tendency to select indicators on what is easily measured. Key conclusions from the workshop are that:

1. indicators are only the starting point;
2. the process of identifying indicators is as important as their measurement;
3. the task of consensus is often political; and
4. triple bottom line research must be open to alternative implementation of social phenomena.

Others have argued that most reports focus on the content, rather than evaluating and reporting what is being learned and actioned through the process and how this impacts on sustainability (Mitchell *et al* 2008).

A guide to reporting environmental indicators for triple bottom line reports was produced by the Australian Government in 2003 (Environment Australia 2003), which outlines environmental management indicators, including links with the Global Reporting Initiative. It is almost universally acknowledged that the Global Reporting Initiative is the emerging international standard for sustainability reporting (Parliamentary Joint Committee on Corporations and Financial Services 2006). This was the most prominent and widely accepted framework from submissions to the Australian Parliament Committee examining corporate reporting (Parliamentary Joint Committee on Corporations and Financial Services 2006).

The Global Reporting Initiative – an international framework

The Global Reporting Initiative (GRI) was convened in 1997 by the Coalition for Environmentally Responsible Economies (CERES) in partnership with the United Nations Environment Program (UNEP) (GRI 2002). It was created to elevate sustainability reporting practices to those of financial reporting.

Effective corporate governance depends on access to relevant, high quality information that enables performance tracking (GRI 2002). The United Nations Environment Program launched the Global Reporting Initiative in 1997. The mission of The Global Reporting Initiative (GRI) is to promote international harmonisation in the reporting of relevant and credible corporate environmental, social and economic performance information to enhance responsible decision making.

The guidelines are for voluntary use by organisations reporting on economic, environmental and social dimensions of their operations performance (Global Reporting Initiative 2002). The GRI framework presents reporting principles and specific content indicators to guide the preparation of organisational-level sustainability reports. It is possible for organisations to produce an “in accordance” report for organisations ready for a high level of reporting, or they may report using the incremental process, which is targeted for those organisations starting out with a reporting process.

The most widely used GRI guidelines were published in 2002 (GRI 2002). They present reporting principles and specific content to guide the preparation organisational sustainability reports, so that they are balanced and present a reasonable picture of their economic, environmental and social performance. They promote comparability while taking into account practical considerations of disclosure. They support benchmarking and assessment of sustainability performance. They serve as an instrument for stakeholder engagement.

The GRI has recently completed a process to innovate and update the GRI guidelines, indicators and reporting processes and these new guidelines known as “G3” were launched 5th October 2006 (GRI 2006). These guidelines provide a framework with guiding principles that result in comparable reports across a diverse range of sectors and organisations.

The GRI initiative provides important guiding principles for industry sectors and companies to base their reports (GRI 2006). It also provides different levels or tiers of reporting compliance to cater for large and small organisations. Reports do not need to contain a detailed check list showing that all principles have been adopted, but they should offer some discussion of how the principles should be applied. The principles aim to ensure reports present a balance of economic, environmental and social performance, facilitate comparison over time and across organisations and address issues of concern to stakeholders. These principles are listed in Table 5, on the following page.

In 2002, 100 organisations had used the GRI guidelines; by the end of 2006 this has risen to 950 worldwide (GRI 2006). Over 1000 organisations declared the use of the GRI guidelines in their sustainability reports in 2007 and 1600 organisations as at 17th October 2008 (www.globalreporting.org).

A search of the GRI database found, as at 15th October 2007, 67 organisations had been listed by the Global Reporting Initiative as reporting using the framework in Australia. These include large ASX companies such as Amcor, BHP, Australian Gas Light Company (AGL), Insurance Australia Group (IAG), and

Westpac. It also includes many energy and water utilities such as Sydney Water, Murray Irrigation, Yallourn Energy, Orgin Energy, and Integral Energy. There are several other mining (Arygle Diamonds, Newcrest), automotive (Ford, Holden), construction (Transfield and Theiss), Telecommunications (Singtel Optus and Telstra) and other financial service companies (ANZ, NAB, VicSuper Ltd) (GRI 2007 as at 15th October 2007, www.globalreporting.org). In October 2008, the GRI and St James Ethics centre signed an agreement to establish an Australian office (GRI media release 17th October 2008) .

A notable gap is the lack of agricultural companies and organisations in the list. Further evidence of the lack of agricultural participation is that GRI has produced sector specific supplements to enhance the generic principles, but agriculture is a notable omission from these sector supplements which include energy, mining, telecommunications, automotives, finance and other sectors. The GRI has commenced a food processing sector supplement (GRI 2008), but its focus is on the manufacturing aspects of the food production chain, although it is expected some reporting of agricultural processes could be included.

There are many other frameworks that offer indicators and reporting benchmarks; some examples include:

- OECD Agri-Environmental Indicators (www.oecd.org/document);
- Sustainable Agriculture Initiative for food industries (<http://www.saiplatform.org>); and
- International Standards for Business, Government and Society Organisation ISO 9000 & 14000 series (www.iso.org).

SUSTAINABILITY INDICATORS FOR AGRICULTURE IN AUSTRALIA

The Australian Government Standing Committee on Agriculture and Resource Management developed a set of measurable attributes to provide a basis for sustainability assessments. These included five key indicators; long term net farm income, natural resource condition, off site environmental impacts, managerial

skills and socio economic impacts (SCARM 1998). These five key indicators were then broken down into 19 attributes (Table 6).

The National Land and Water Resources Audit Australian Agriculture Framework for Economic and Social Indicators (NLWRA 2005) concluded that the three main economic indicators that provide an indication of the contribution of agriculture to sustainable development include wealth, income and productivity. The report concluded that information on social outcomes is harder to define and measure than economic and

Table 6 The SCARM sustainability indicators

INDICATOR	ATTRIBUTE
Long term net farm income	Real net farm income
	Total Factor productivity
	Farmers terms of trade
	Average real net farm income
	Debt servicing ratio
Natural resource condition	Nutrient balance P & K
	Soil condition: acidity and sodicity
	Rangeland condition and trend
	Agricultural plant species diversity
	Water utilisation by vegetation
Off site environmental impacts	Chemical residues in products
	Salinity in streams
	Dust storm index
	Impact of agriculture on native vegetation
Managerial skills	Level of farmer education
	Extent and participation in Landcare
	Implementation of sustainable practices
Off site socio economic impacts	Age structure of the workforce
	Access to key services
Source: SCARM 1998	

Table 5 The Global Reporting Initiative Guiding Principles

PRINCIPLES	EXPLANATION
Principles for defining the content	
Materiality	Reflect significant economic, environmental and social impacts
Stakeholder inclusiveness	Internal and external stakeholders
Sustainability context	Report should include context within broader context on the nation or globe
Completeness	Encompass dimensions of scope, boundaries and time
Principles for defining quality	
Balance	Positive and negative aspects of organisation
Comparability	Information needs to be consistent
Accuracy	Information needs to be accurate
Timeliness	Report on a regular schedule
Clarity	Information should be understandable and accessible
Reliability	Quality assurance
Reporting guidance for boundary setting	Report should cover all entities that generate significant sustainability impacts.
Source: Global Reporting Initiative, G3 Guidelines 2006	

environmental information. These indicators are summarised in Table 7. Other economic indicators proposed have been return on capital (Hassall & Associates 2005). Hassall & Associates (2005) also proposed participation, development of property plans and capacity as other social indicators for the grains industry.

To further build on the SCARM (1998) indicators project and further develop means of reporting on the contributions made by Australia's primary industries to ecologically sustainable development the National Land and Water Resources Audit, Department of Agriculture Fisheries and Forestry and various Rural Research and Development Corporations are collaborating on a project known as "Signposts for Australian Agriculture – the role of agriculture in natural resource management, economic growth and community life" (Chesson and Whitworth 2005; Chesson *et al* 2007). It has developed a framework for rural industry organisations to measure the contribution to ecologically sustainable development. The contributions of an industry are divided into economic, bio physical and social systems, which are further divided into a component tree. Reports have been completed for grains, beef cattle, cotton, wine, dairy, and horticulture.

As part of the Signposts program, a study on Rural Research and Development Corporations data and reporting concluded they:

- have considerable information, but it is not easily retrieved and there are considerable gaps;
- have access to production data, but do not generally have much specific industry wide environmental data and even less social information;
- are aware of the need to report triple bottom line outcomes, but are uncertain about the magnitude and needs of the audience;
- would welcome means to align reporting and improve their capacity to provide information; and
- are not well resourced or equipped to spatially analyse data (Day 2004).

Cotton industry stakeholders are supportive of improved information management and reporting (SKM 2003; Chesson and Whitworth 2005; Bruce Pyke, CRDC *pers comm.* 2007, Greg Kauter, ACGRA *pers comm.* 2007) and this study project has participated in discussions between the Signposts team and the cotton industry.

SUSTAINABILITY INDICATORS FOR IRRIGATED AGRICULTURE

The Murray Darling Basin Commission was developing sustainability performance indicators as part of their Watermark program, which has since been terminated. The Murray Darling Basin Commission Irrigation Management Information and Reporting System (IMIRIS) project proposed an alternative approach to irrigation data management and reporting (SKM 2003). The study identified that cotton industry wide data exists, but the inefficiency lies in data coordination and little reporting from a strategic perspective on the social, economic, and environmental conditions and trends. The study recommended the next step was to confirm the attributes of all the required datasets.

Despite a culture of sharing information in the cotton industry, one of the major barriers identified was grower mistrust of providing data to government (SKM 2003). Other barriers include the cost of collection and the lack of industry and government knowledge of the correlation between farm practice and broader scale natural resource impacts (SKM 2003). The study suggested indicative costs of improving the reporting system could be in the order of \$250,000 p.a. The SKM (2003) study included consultation with industry representatives on the priority of potential information products needed. These are summarised in Table 8, on the following page.

The Australian National Committee on Irrigation and Drainage (ANCID) produced 65 indicators grouped in four key activity areas (operational, environmental, business processes and financial) for rural water providers (ANCID 2002). More recently, the

Table 7 Possible Economic and social indicators for agriculture

INDICATOR		COMMENT
Economic	Productivity	Total factor productivity is a relative measure of total farm output to total input use, expressed as an index. The NLWRA states this information is available for some agricultural indices, but it is not for cotton. It is also not easy to calculate and not easily understood by the person in the street.
	Farm business profit	These could include net value of production (gross revenue minus production costs) and farm business profit (cash receipts, minus cash costs, plus buildup in trading stocks, minus depreciation and unpaid family labour).
	Wealth	Farm land value which provides a dollar value of the natural resources. The NLWRA (2005) states that this information is also not available for cotton. One of the problems with this suggestion is that it does not include the value of water, which, in the case of cotton businesses, is often more valuable than the land.
Social	Human capital	Number of farm accidents: a measure of reported OH&S level of education and training: a measure of educational levels attained by people employed.
	Social capital	Employment: A measure of the number of people employed in a defined industry or region.
Source: NLWRA 2005		

Table 8 Priority information products of the cotton industry

PRIORITY	INFORMATION PRODUCT
High	Irrigator participation rate in pursuing Best Management Practice (BMP), with analysis of participation and attainment at an industry regional level
High	Sustainability trends analysis generated from data collected through implementing BMP
High	Cotton growers licensed water allocation compared to actual water used analysis
High	Cotton growers production volume compared to water use (by river valley)
High	Cotton industry report card on river health
High	Report card on the socio economic effects of the cotton industry, including % of population employed
Medium	Report card on the costs to cotton growers of government reforms and regulations
Low	Cotton industry water trading analysis
Low	Outlook for BMP adoption
Low	Comparative analysis of industry adoption of BMP

Source: SKM 2003

Cooperative Research Centre for Irrigation Futures undertook a sustainability challenge project to encourage triple bottom line reporting for continuous improvement and enhanced sustainability within some rural and urban case study regions (Christen *et al* 2006). Their report notes the occurrence of triple bottom line reporting is more prevalent amongst potable water supply businesses such as Sydney Water and Melbourne Water in Australia. They also noted some incidence of triple bottom line reporting in rural or irrigation water supply companies such as Murray and Murrumbidgee Irrigation.

State of Environment reporting is now undertaken by the Australian Government. Detailed sets of environmental indicators have been developed in Australia for the State of Environment reports. The first report was completed in 1996 and followed up by a subsequent report in 2001 and 2006. The report compiles “favourable and unfavourable news” (data) in thematic areas of atmosphere, coasts and oceans, land, inland waters, and human settlements (AGSOE 2001). The Australian Government State of Environment Report (2001) states that reliable data and information are still key issues for State of Environment reporting in Australia. Major difficulties occur regarding access to data, consistency of standards and lack of relevant information. A set of 75 core indicators are used by these reports.

The most recent State of Environment report was released in December 2006. It is the third independent report on the state of Australia’s environment since 1996. The 2006 document includes individual reports on 263 environmental indicators, 8 theme commentaries, 10 integrative commentaries on important environmental issues for Australia and 33 short reports on

important but discrete current or emerging issues (Beeton 2006). Whilst progress has been made to develop indicators there is still not enough good quality accessible data on the environment (Beeton 2006).

Regional catchment health indicators have been under development for sometime. Walker *et al* (1996) provided an overview of some possible catchment health indicators. Over the last decade the Federal and State Governments have devoted significant resources to regional standards and targets. The National Resource Management Monitoring and Evaluation Framework lists indicators and reporting for regional bodies to use for monitoring changes in resource condition and these can be found on www.nrm.gov.au (Australian Government 2003).

State Governments vary in the specific details concerning how they manage and monitor land management. However, by way of example in NSW where seventy percent of the cotton industry is located in Australia, this task is overseen by the Natural Resources Commission. The Natural Resources Commission has developed state-wide standards and targets for natural resource management (Table 9) (NRC 2005). Processes are being developed for the monitoring and evaluation of these state wide targets; however, a major problem is the lack of benchmarking data so that changes can be monitored into the future. There are also no regular systems in place to measure many of these attributes such as soil condition.

Kemp *et al* (2001) argues that the focus should be on farm level indicators rather than regional indicators because it is only within the confines of the farm where management can effectively maintain environmental integrity. They also note there has been a proliferation of benchmarking schemes with resultant confusion in the minds of end users.

As a global food producing company Unilever Ltd has adopted set of eleven sustainable indicators shown in Table 10 for their commodities and are now testing them in the field with those who produce their key crops of palm oil, peas, spinach, tea and tomatoes (McMaster and McMaster 2001). They found whilst every environmental indicator could be measured, there is no consensus on how to measure environmental indicators at a farm site level. Costs of data collection and management was also a major factor to consider.

KEY IMPACTS OF COTTON PRODUCTION

There have been several examples of prosperous cotton industries around the world which collapsed, at least temporarily, due to unsustainable practices. Examples include:

- the dustbowl of the southern states of the United States of America in the 1930’s due to drought and unsustainable soil management practices such as stubble burning, and bare soil crop rotations (Worster 2004);
- the Aral Sea in central Asia (of the former USSR) where excess water extraction has led to the drying up of the Aral Sea. Low irrigation efficiencies have resulted in water logging of crops, rising groundwater levels and soil salinity. Nearly half the land in the region is affected by salinity (Dukhovny *et al* 2002);

- in the north-east Mexico, the tobacco budworm *Heliothis virescens* developed resistance to a range of insecticides as a result of excessive insecticide use and cotton production declined from three quarters of a million acres to almost zero acres during the 1960s (Metcalf and Luckmann 1994);
- in Thailand, pyrethroid resistance in *Helicoverpa armigera* first occurred in 1983 at the same time as it did in Australia. The Thais did not institute a resistance management strategy, which Australia did, and the cotton growing industry in Thailand collapsed (Cox and Forrester 1992); and
- in the Ord River region of Western Australia, *Helicoverpa armigera* became resistant to DDT in the early 1970s and production ceased in 1975 (Wilson 1974).

Cotton growing in Australia has had both positive (for example, employment and economic growth) and negative (for example, fish kills and spray drift problems) impacts on the landscape.

In 1991, the Australian Cotton Foundation commissioned an independent environmental audit of the cotton industry as at the time the industry was subject to criticism from the public over the use of pesticides and fish kills. The audit grouped a total of 69 environmental and occupational health and safety recommendations under the general headings of land use, pesticide use, water use and cotton processing (Gibb 1991). In 2003, a follow up audit was commissioned by the Cotton Research and Development Corporation. This audit found that the cotton industry had vastly improved since the 1991 audit and noted the main issues for improved performance were water management, pest management and pesticide use and waste management (GHD 2003).

Common community concerns in relation to cotton production include impacts on aquatic ecosystems, groundwater and river health; changes to biodiversity and species diversity; soil degradation, soil loss and salinity; chemical use and waste management; odours, dust and noise; land and vegetation management; weeds and pests; transgenic crop technologies; and air pollution, greenhouse gas emissions and energy use. These aspects and impacts are raised here because people want to know information about them in the context of sustainability reporting.

In response to these many concerns about cotton production, the industry established its Best Management Practices Program to improve farm management practices. Since 1997, the Australian cotton industry has had a voluntary environmental management system – branded as Best Management Practices program (BMP) in place and an overview of the program can be found in Williams *et al* (2004). The program includes a comprehensive manual, substantial implementation support and an audit program. The audits verify the compliance of the farm with the manual and hence an objective assessment on farm practices. One of the challenges with BMP has been monitoring and reporting the benefits of the program to growers, government and the community. Chapter 6 will report a review of BMP data and explore this in more detail.

The cotton industry needs to develop indicators to measure and report on its sustainability using a triple bottom line framework of economic, environmental and social parameters. For the 3rd

Table 9 NSW state wide resource condition targets by 2015

CATEGORY	STATE WIDE RESOURCE CONDITION TARGET BY 2015
Biodiversity	Increase in native vegetation
	Increase in sustainable populations of a range of native fauna species
	Increase recovery of threatened species, populations and ecological communities
	Reduction in invasive species
Water	Improvement of riverine ecosystems
	Improvement of groundwater systems to support ecosystems and uses
	No decline in marine waters ecosystems
	Improvement in condition of important wetlands
Land	Improvement in condition of estuaries
	Improvement in soil condition
Community	Increase in area of land managed within its capability
	Natural resource decisions contribute to improving or maintaining social well being
	Increase in capacity of natural resource managers to contribute regionally

Source: NRC 2005

Table 10 Eleven sustainable indicators used by Unilever Ltd

INDICATOR	POSSIBLE PARAMETERS
Soil fertility/health	Beneficial organisms eg earthworms / m, soil organic carbon
Soil loss	Soil cover index, soil erosion
Nutrients	Inorganic inputs / tonne of product, N fixed, N loss emissions
Pest management	Amount of pesticides, type, percentage crop under IPM
Biodiversity	Species on site / off site; species of birds, butterflies, farm landscape for natural predators
Value chain	Value product / ha, yield, quality, costs
Energy	Energy inputs, emissions to air
Water	Use per ha or tonne of product, leaching, water quality
Social /human capital	Group dynamics, awareness of sustainability, rate of innovation
Local economy	Amount of money reinvested locally, employment
Animal welfare	Feeding, housing, freedom from abuse

Source: McMaster and McMaster 2001

World Cotton Research Conference, South Africa, Roth (2003) selected a summary of possible economic, environmental and social indicators in relation to cotton production in Australia (Table 11). This project will aim to populate these indicators, and identify any gaps or additions.

Key stakeholders and needs

Preparing a sustainability report requires the identification of key stakeholders and needs. Stakeholders include individuals and organisations from industry, government, non government organisations and the community. Industry stakeholders include peak organisations such as Cotton Australia, National Farmers Federation, Cotton Research and Development Corporation, individual growers, people working within the industry such as cotton consultants, cotton buyers and processors, input providers, researchers, bankers and many others. The main Government stakeholders are within the Federal, NSW and Queensland Governments and include Departments related to primary industries, environment, water and trade. Other relevant government agencies include regional natural resource management bodies and the new Murray Darling Basin Authority. Local Government is another important stakeholder and is closely tied to the mood of the community. The communi-

ty and other non government organisations such as conservation groups and chambers of commerce are important stakeholders.

As part of this project a workshop was conducted 12th December 2006 at the Australian Cotton Research Institute with a range of stakeholders from industry, regional natural resource catchment bodies, local government, and state government. The aim was to discuss possible indicators and data needs. A background paper was prepared for the workshop. Table 12 provides a summary of the suggested sustainability indicators from the workshop.

Table 11 Possible economic, environmental and social indicators of sustainability in relation to cotton production in Australia

ECONOMIC	ENVIRONMENTAL	SOCIAL
Yield (per/ha, per unit of water used ML)	Chemical use	Employment/unemployment (including age, gender, salary, sector trends)
Profit (\$/ha, \$/ML)	Water quality (eg P,N,EC, pH, turbidity, pesticides, nutrients, biological)	Occupational Health and safety (accidents)
Operating costs (\$/ha, \$/bale, eg fertilizer, chemical, water, labour, etc)	Water use (surface/groundwater, efficiency ratios, drainage, water table)	Education, training and skills of people
Capital costs and value (eg machinery, land, etc)	Salinity and sodicity	Population levels and trends
Income (\$/bale)	Energy and greenhouse	Attitudes and perceptions by the community towards cotton
Financial ratios (eg return on assets, debt, etc)	River health (flows, water quality, riparian vegetation, indexes)	Technology access and adoption
Industry gross value of production	Soil health (eg OM, C, pH,N,P,K, EC, ESP%, biology, soil structure etc)	Farmer groups and industry networks/ associations
Industry contribution to exports and gross domestic product	Biodiversity (Pick a focal species such as birds, native vegetation, or fish)	Stewardship of transgenic technology and community/market acceptance
Employment	Landscape and catchment biophysical indicators	Community and infrastructure indicators
Cotton fibre quality parameters (length, strength, micronaire, colour, etc)	Weeds, insect pests, and diseases	Research and development activities
	Compliance with Industry codes and Best Management Practices	
	Air pollution	
	Transgenic crop technologies	
	Resistance levels of pests to management tools (insecticides, transgenic traits)	

Source: Roth 2003

Table 12 Possible sustainability indicators from a Narrabri workshop in 2006

OUTCOME	POSSIBLE INDICATORS
Economic	
Regional and export income	<ul style="list-style-type: none"> • Value of production • Export income
Regional employment	<ul style="list-style-type: none"> • People employed • Productivity per man hour • Hours worked per bale
Industry trends	<ul style="list-style-type: none"> • Farm numbers / area
Profitable farming	<ul style="list-style-type: none"> • Gross profit • Farm income diversity (including off farm) • Costs • Capital investment and return
Continual improvement in production	<ul style="list-style-type: none"> • Yield
Accountability to taxpayers	<ul style="list-style-type: none"> • Funding received from Government programs
Environmental	
Water: Explaining trends of water quality in catchments	<ul style="list-style-type: none"> • Quality (turbidity, N&P, EC, pesticides) • Access/fairness • Efficiency of use and comparisons
Land: Sustainable soils, responsible pest management, responsible transgenic crop stewardship	<ul style="list-style-type: none"> • Soil health (nutrients, EC, structure, sodicity, Organic C) • Weeds (and escapees) • Pest management (spray drift implications) • Transgenic or genetically modified traits (resistance, stewardship)
Biodiversity: Contribution to ecology of region and nation	<ul style="list-style-type: none"> • Environmental weeds • Riparian health including connectivity • Aquatic biodiversity • Native vegetation (spray drift impacts, quantity, quality) • Native fauna / bugs
Climate: Responsible energy use, compliance with Government policy and contributing to climate change mitigation	<ul style="list-style-type: none"> • CO₂ Emissions • Carbon storage • Energy use
Social	
Measure of the human capital of the industry. The capacity of the workforce to achieve tasks and adopt new practices.	<ul style="list-style-type: none"> • Education • Training • Education • Qualifications of farmers and people in the industry
Explaining trends of how people are involved in the cotton industry	<ul style="list-style-type: none"> • Demographics • Age • Distribution • Gender • Population
Value of the workplace and industry to the community	<ul style="list-style-type: none"> • Employment / unemployment • Numbers • Income levels • Hours worked • Turnover of employees • Distribution
Healthy and safe industry and work practices	<ul style="list-style-type: none"> • Health • Farm accidents (deaths, injury) • OH&S
Reputation of the cotton industry by stakeholders. It provides the "social licence" to farm.	<ul style="list-style-type: none"> • Community attitudes / perceptions • Pesticides • Water • Transgenic cotton technologies
Playing a part in the community. Knowledge diffusion and cooperative behaviour for mutual benefit.	<ul style="list-style-type: none"> • Social capital and fabric • Industry networks • Memberships • Participation in activities
Innovation & desire to improve practices, human and social capital	<ul style="list-style-type: none"> • Research and development • Investment and priorities
Evidence of doing the right thing	<ul style="list-style-type: none"> • Number of prosecutions • Water and land management offences / fines • Complaints

CONCLUSION

The concept of sustainability is a widely used expression and aspirational goal of society. Aspirations are easy to state, but gaining agreement on what is a sustainable practice has proven challenging. The concept of sustainability is broadly agreed as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. There is a growing expectation that business, including farms, whilst being economically viable are socially and environmentally responsible. The role of agriculture in the sustainability of the globe is critical given the importance of agriculture for food and fibre production and the large portion of Australia's land and water managed by farmers.

There is increasing interest in sustainability reporting around the world. Sustainability reporting is the practice of measuring and disclosing organisational performance for economic, environmental and social attributes. There are many benefits such as risk reductions, market opportunities, cost reductions, management tool, and enhanced company reputation. There are also many barriers to adoption, which include cost, determining indicators to monitor and sensitivities related to public disclosure. The data from sustainability indicators can be used for accountability, to assess conditions and trends and make comparisons, assess changes in practices or policies, planning, reporting and communication activities. Characteristics of good sustainability indicators include they must be measurable, easy and cost effective to collect, reliable, unambiguous and free of bias, related to industry actions in a timely manner, and have a broad coverage of economic, environmental and social factors.

The agricultural industries have shown interest and willingness to participate in sustainability reporting, but to date have not become highly active public reporters, which is due to the dynamic nature and complexity of measuring the many aspects of agricultural systems, compared to a factory or banking organisation. Agriculture is also collectively a large industry made up of many separate privately owned farm business. The benefits of sustainability reporting are not yet tangible enough for it to become a mainstream activity.

Growing interest in sustainability has led to a proliferation of stakeholders demanding information. Consumers are now demanding information on the origin and processes used to manufacture their food and clothes. The Global Reporting Initiative is emerging as the international standard for sustainability reporting and, despite its challenges, is rapidly becoming a mainstream business practice.

There is a vast amount of information that could be collected and processed for reporting the sustainability of agriculture. The greatest challenge is capturing this information in a useable and cost effective manner. Organisations generally are able to report their economic information. There are many possible indicators for the environmental sphere, but some such as biodiversity are difficult to define and monitor. There is general agreement that the social indicators are the most difficult to define and monitor. There is no consensus on how to measure environmental and social indicators at the farm scale.

It will not be possible to monitor and report every possible indicator. There is a need to be pragmatic and get started rather than continually trying to define the perfect set of indicators. Sustainability is a journey rather than a destination. Once an industry has reviewed what sort of information it has, changes can be implemented for future reports following further stakeholder input. The ultimate goal is to report and monitor things over decades.

The following chapters compile an economic, environmental and social data for the Australian cotton industry.

3 ECONOMIC INDICATORS OF THE AUSTRALIAN COTTON INDUSTRY

INTRODUCTION

This report uses a triple bottom line framework to present economic, environmental and social attributes of the Australian Cotton Industry. The data presented in this chapter are economic indicators commonly requested by stakeholders for the cotton industry. Section 3.2 provides a brief overview of the cotton industry, and the details are further expanded in the other sections of this chapter.

A BRIEF OVERVIEW OF THE AUSTRALIAN COTTON INDUSTRY

Cotton has been an important fibre and fabric for over 5000 years. It was widely used and traded. Every day, everyone wears cotton clothing and uses products made from cotton seed oil. Cotton is the most commonly produced natural fibre in the world and represents about 46 per cent of the world textile market. By contrast, in the world marketplace, wool accounts for 3 per cent, and other natural fibres like silk, hemp and mohair make up a very small proportion of textiles (less than 1% each). Synthetic or man-made fibres make up 51 percent of the global textile market and this proportion is increasing.

About 300 kilograms of fuzzy cotton seed is produced for every 227 kilogram bale of cotton fibre. Cotton seed is a by-product of the more valuable cotton fibre (or lint), and makes up about 15 per cent of the total financial returns to farmers. Cotton seed is a valued raw material for food oils for human consumption and high protein feed for livestock and is currently valued around \$300/tonne. A cotton bale of lint is typically worth about \$430/bale. Financial returns for cotton production are about \$4000 / ha of income with a net profit before interest of \$500/ha.

Although cotton was introduced to Australia with the First Fleet, it was not until the 1860s during the American civil war that cotton became an important crop. Very little cotton was produced between 1880 and 1920. From 1920–1960 it was grown on a small scale as a dryland crop in Queensland. Yields were less than 180 kg/ha. The most dramatic change to cotton production followed the completion of Keepit Dam on the Namoi River, NSW and the subsequent introduction of irrigation in northern NSW during the 1960/70s. Rapid expansion in the 1980s led to the development of the cotton industry as it is today. There are about 800 cotton farmers in Australia and about 10,000 people employed by the industry. Seventy per cent of Australia's cotton is grown in NSW with the remainder grown in Queensland. Cotton growing is also being trialled in northern Australia in the Ord, Western Australia and the Burdekin, north Queensland (Figure 1).

Some general characteristics of farms that grow cotton as the main irrigated activity are shown in Table 13, on the following page. These farms typically grew 414 hectares in 2002–03 and 343 hectares in 2003–04 of cotton, which makes up the majority (about 85%) of the area of irrigated crops grown on the farms. Table 13 shows that cotton makes up the largest proportion of farm income (gross value of production), 82% in 2002–03 and 66% in 2003–04 and highlights the economic importance of cotton where it can be grown. Both these seasons were drought

affected compared to the previous 6 years, but are a reasonable representation of an average for the last 10 years.

Table 13, on the following page, highlights that that total farm sizes are typically much larger (>4,000 ha) as they comprise of areas for other crops, crop fallow areas, pastures, roads, irrigation channels, and native vegetation. Based on these figures the cotton area is about 10% of the total farm area. About 80 per cent of farms are irrigated and they generally produce cereal crops like wheat and sorghum and beef cattle as part of the enterprise mix.

Up to 400,000 hectares of irrigated cotton are grown in Australia depending on water availability. The area of rain grown or dryland cotton changes considerably from year to year depending on rain and prices. The dryland area ranges from 5000–120,000 hectares, produced by up to 450 growers, with yields ranging from 200–1600 kilograms per hectare. On a global scale, Australia is a relatively small producer of cotton, growing about 3 per cent of the world's cotton. The largest producers are currently (in order) China, India, USA, Pakistan, Brazil and Uzbekistan.

Figure 1 Existing and potential cotton regions in Australia



Table 13 Characteristics of farms with cotton as the main irrigated activity

CHARACTERISTIC	UNIT	AVERAGE FIGURE 2002–03	AVERAGE FIGURE 2003–04
Area of holding	ha	4,387	4,404
Area irrigated	ha	494	404
Area irrigated (cotton)	ha	414	343
Water use (farm)	ML	2,922	2,541
Water use (cotton)	ML	2,697	2,334
Water use intensity (cotton)	ML/ha	6.1	6.0
Farm dam capacity	ML	3,269	
Gross value of production (farm)	\$	1,776,000	1,795,000
Gross value of production (irrigated cotton)	\$	1,447,000	1,184,000
Gross value of production (all irrigated crops)	\$	1,520,000	1,265,000

Source: Data modified from ABS 2006

Table 14 A summary of the main seasonal factors for cotton from 1999–2008

YEAR	KEY SEASONAL EVENT	SEASONAL FACTORS FOR THE COTTON SEASON
2000–2001	Record year for production 3,500,000 bales	Good water supplies and prices resulted in a large planting area. Heavy rain in November and February caused flooding and destroyed large areas of crop. It was also a hot growing season. First BMP bale produced. Single gene <i>Bt</i> cotton (Ingard) area was increased and capped at 30%.
2001–2002	3,000,000 bales	This season had a wide range of weather conditions. Very dry around planting, which resulted in a small dryland crop. Early season from Oct–Dec was cold, but it then remained hot with clear skies that produced record yields at the time. Insect pressure was low, which helped reduce production costs. Prices were low. Production fell from 500,000 ha to 400,000 ha.
2002–2003	Drought	Production fell back to the level of 10 years ago due to the worst drought for many years. Above average day degrees and very few overcast days contributed to record yields where growers had water. IPM and area wide management were key pest management strategies in another low pest pressure year.
2003–2004	Drought, small planting area. Bollgard® crops first planted.	The smallest area of cotton harvested in 20 years due to drought. Prices dropped from \$600 / bale to \$350 /bale. Insect pressure was higher than the previous two seasons. Good yields were achieved for growers with adequate water helped by some timely rain. This was also the year two gene <i>Bt</i> cotton, Bollgard was first grown.
2004–2005	An ideal season. Best ever quality and yields.	An ideal cotton growing season that that resulted in record yields. Insect pressure was light. With the exception of the Macquarie Valley which continued to suffer from drought growers had enough water, and received appropriate temperatures and plenty of sunlight to grow world record yielding crops. Best ever crop in terms of quality.
2005–2006	Very hot season	Crops had a good start due to warm conditions and it was very hot mid season. Accumulated day degrees were well above average and many regions experienced twice the number of days above 36 degrees. It was a good year, just not an exceptional year. Hot temperatures and drought caused slightly lower yields.
2006–2007	Record yields. Ideal season.	Most regions experienced little rainfall. Pest pressures were very low. For growers with adequate water it was an ideal season with hot, sunny conditions, but not the temperature extremes of previous years. Lint prices were also low, although the drought boosted cotton seed prices. The good growing conditions resulted in record yields.
2007–2008	Smallest planting in 30 years. Cool season.	Severe drought conditions and well below average rain. Some cold weather, the coldest for many years, which resulted in below average day degrees. In January 2008 there were flooding rains in Emerald and most parts of Queensland. The pale cotton stainer bug was a surprising problem.
2008–09	Summer rain and good yield	There was an increase in the planted area, due to good pre-season and planting rain. Temperatures were milder than previous summers. While not as high as the previous record season, yields were high.

Source: Roth unpublished. Various Australian Cottongrower magazines were used to compile the table

The major buyers of Australian cotton (in order) are currently China, Indonesia, Thailand, South Korea, and Japan. Australia has a reputation for producing high quality cotton. There is no government intervention in the growing or marketing of the crop. Since 1980, the value of Australian cotton produced annually has increased dramatically to about \$1.4–1.6 billion per annum. In recent years this gross value of production has fallen to less than \$1 billion due to drought conditions.

Since 1960, lint yields have steadily increased at about 30 kilograms of lint per hectare per year. Australian average yields are now the highest of any major cotton producing country in the world and yields have continued to edge upwards from 1200 kg/ha in the 1970s, through 1400 kg/ha in the 1980s to 1600 kg/ha in the 1990s and are now around 1900 kg/ha. This is three times the world average yield. Research, combined with its practical implementation by Australian cotton growers, has underpinned these significant increases in production.

There is considerable variation in the seasonal performance of cotton, which is caused by a many factors. Table 14 summarises some of these key seasonal factors and events.

Industry organisations

The Australian cotton industry is made up of many diverse individuals and organisations. The Australian Cotton Industry Council (www.acic.org.au) is a whole of industry forum for sharing information, discussing strategies and promoting cooperation between industry organisations. It includes growers, researchers,

ginners, classers, marketers, consulting agronomists, chemical and seed suppliers.

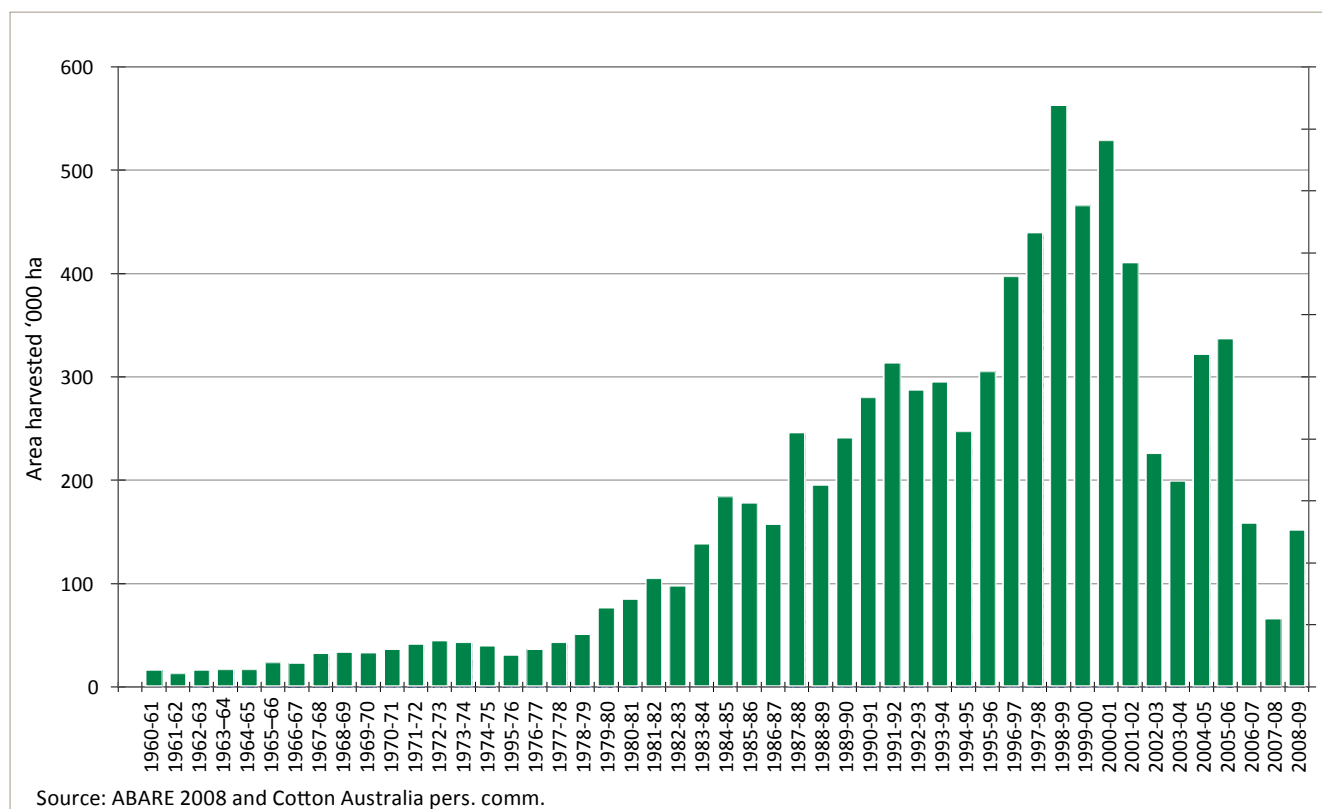
Cotton Australia (www.cottonaustralia.com.au) is the peak body for Australian cotton growers. It is funded by a voluntary levy paid by growers on the amount of cotton they produce. Cotton Australia supports a regional cotton growers association in each region where cotton is produced. It is governed by a board elected by grower members. Cotton growers also pay a compulsory research and development levy, which is matched by the Australian Government and managed by the Cotton Research and Development Corporation (www.crdc.com.au).

COTTON PRODUCTION AREA

Figure 2 shows the area of cotton harvested has generally steadily increased since 1975–76 each year up until the 1999–00 crop, with the exception of drought years such as 1988–89 and 1992–1994. Since 2000–01 the cotton area harvested has declined significantly due to continuing drought conditions and water shortages in both Queensland and NSW.

The area planted from 1995–96 to 1999–00 averaged 433,000 ha, while from 2000–01 to 2004–05 the average area fell to 336,000 ha. Due to drought conditions in 2006–07 the crop area fell to its lowest level in 24 years, 142,000 ha, which was 37% less than the previous 10 years. In 2007–08 the area fell further to 64,885 ha, which made it the smallest crop since 1978–79. This was due to negligible irrigation allocations, lack of rain, relative poor cotton prices compared to other crop options such as sorghum where the drought was fuelling higher prices due to

Figure 2 Area of Australian Cotton harvested 1960–2009



stock feed requirements. The 2008–09 cotton crop planting area forecast is 150,800 ha (22 December 2008) (Cotton Australia, pers comm.).

The area of cotton planted in each of the cotton growing regions of NSW and Queensland from 2000–01 to 2008–09 is shown in Figures 3 and 4. The Gwydir valley is the largest cotton growing region, followed by the Namoi, Macintyre, Darling Downs and Macquarie regions. There is considerable variation in the regional plantings, which is caused by water availability. For example, the Macquarie valley has experienced a decline from around 50,000 ha to less than 5000 ha in 2008–09. Bourke, Menindee, Walgett and Dirranbandi have each experienced a year of no plantings in the last 5 years. Following extensive rain

in 2008, most of the Queensland valleys have increased plantings in 2008–09 compared to previous two seasons. In the Burdekin region (not included in Figure 4), 1,100 ha have been planted in 2008–09 as sugarcane growers look to diversify their cropping options (Cotton Australia, pers comm.). Extensive agronomic trials are now underway in the Burdekin. Trials are also being conducted in the Ord region, Western Australia and the results are summarised in Yeates *et al* (2007).

COTTON YIELDS

Australian cotton yields have increased significantly each year (Figure 5). Given the industry was going through an establishment phase in the 1960s it is more relevant to examine yield in-

Figure 3 Queensland regional cotton planting areas 2000-2009

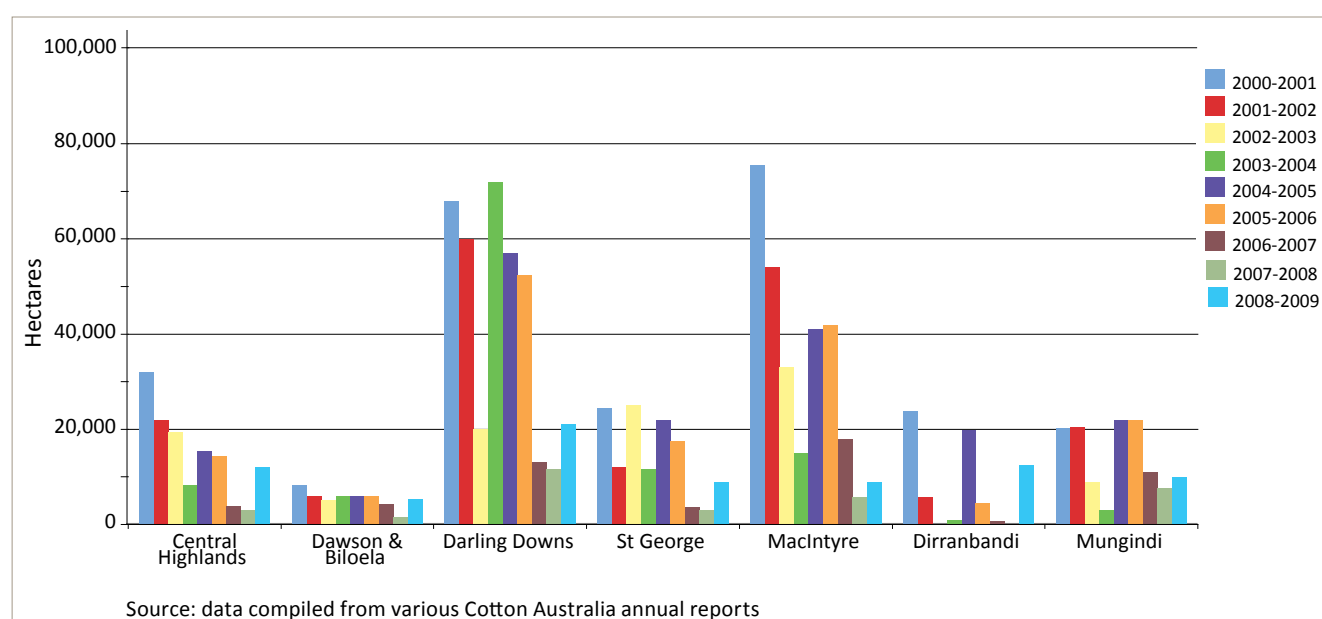
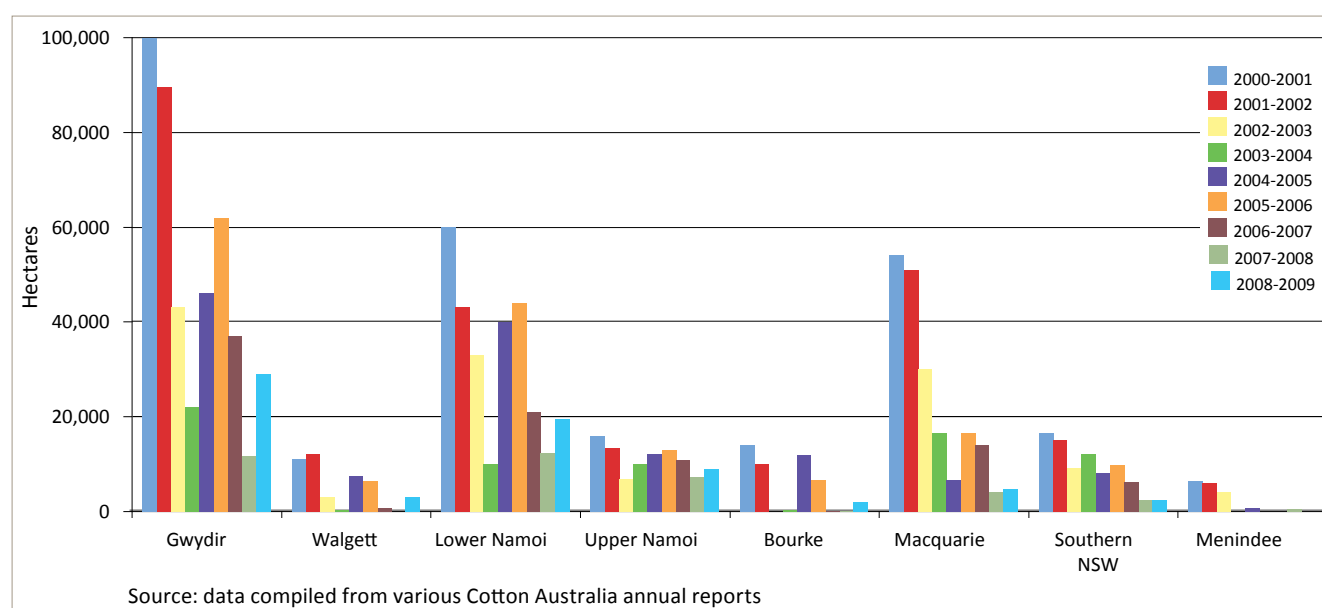


Figure 4 New South Wales regional cotton planting areas from 2000 -2009



creases in recent periods. During the last 20 years, cotton yields have increased on average at 32.9 kg of lint per hectare per year.

Figure 5 shows that yields have varied from year to year depending on seasonal conditions. In the 1970s wet seasons, floods, pest and disease problems hindered cotton yields. Synthetic pyrethroid insecticides were introduced in the late 1970s and had an immediate beneficial impact. At the same time cotton varieties with resistance to bacterial blight and verticillium wilt emerged which also help boost yields. The droughts in the early 1980s and mid 1990s reduced yields as a result of lack of water for adequate crop irrigation. Other seasonal factors have taken their toll on yields including wet harvests and high pest pressure seasons.

Australian average lint yields are now the highest of any major cotton producing country in the world and yields have continued to edge upwards from 1200 kg/ha in the 1970s, through 1400 kg/ha in the 1980s to 1600 kg/ha in the 1990s and are now around 1900 kg/ha. Some countries that grow small amounts of cotton, such as Israel do have higher yields, but their total area of production is less than the Namoi valley. According to the International Cotton Advisory Committee forecasts, the average yield during 2006–07 in the world was expected to be 716 kg/ha (Chaudhry 2006), which equates to 3.16 bales/ha. Figure 5 shows that Australian cotton yields are almost three times the world average.

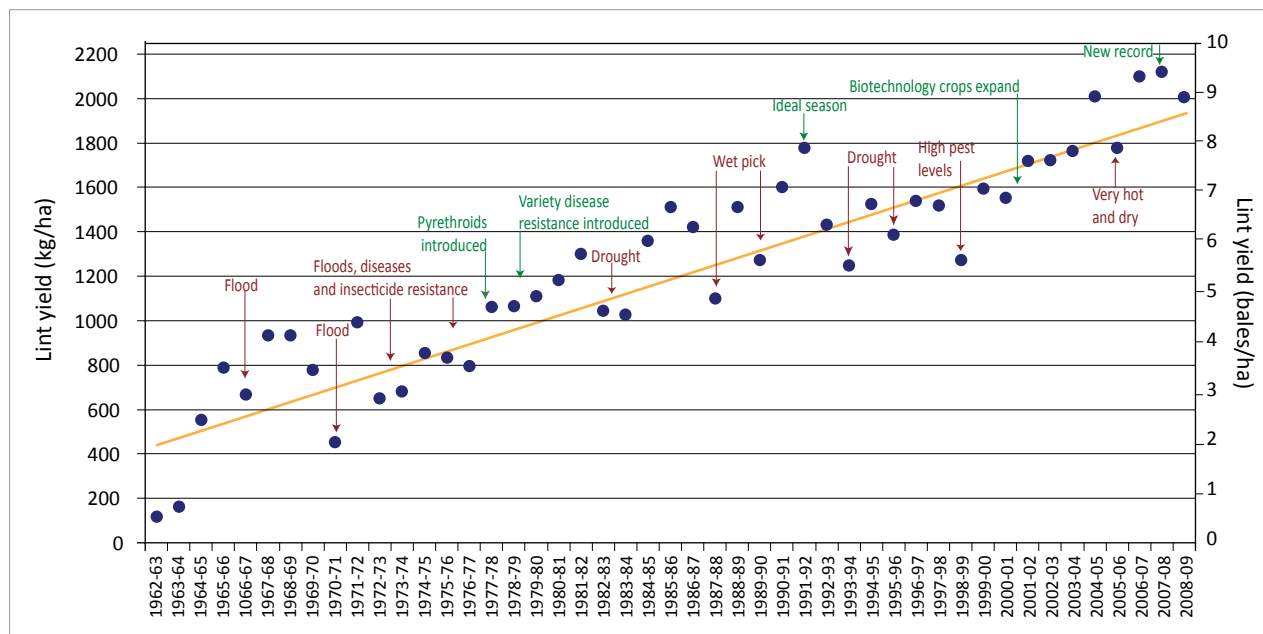
Whilst average yields are useful for presentation purposes they do not show the considerable variability in yields achieved by cotton growers. For example, between 1999–2004, for 1008

cotton fields in the Emerald region the average yield was 7.9 bales/ha, with a range in yields was from 4.2 to 12.8 bales/ha (David Kelly, QDPI&F, Emerald, pers comm.). Parkes (2004) reported cotton yields from his farm near Moree for 2002–03 season. The mean yield was 15.1 bales/ha whilst the range was 9–17 bales/ha. Cotton Seed Distributors Ltd has been undertaking commercially grown, replicated trials variety trials in all the cotton valleys for many years. The average yield in their 3 years of trials for 843 sites between 2005 and 2007 was 8.98 bales/ha. The median yield was 9.62 bales/ha and the range was from 1.41 bales/ha to 13.93 bales/ha. The low yielding site was an old variety grown as dryland cotton, whilst the high yielding site was a common variety (Sicot 71) grown under irrigated conditions. This data indicates there is considerable potential for crop yields to further increase for the foreseeable future. Cotton Seed Distributors publish their trial data each year for each region, which can be found on their internet site; www.csd.net.au.

GROSS VALUE OF COTTON PRODUCTION

The gross value of cotton produced in Australia for the last 20 years is shown in Figure 6, on the following page. It has increased rapidly, with the exception of the drought years 1992–94, 1998–99. The gross value of production peaked at \$1.9 billion in 2000–01 and for the last few seasons has been falling; \$1.2 billion 2004–05, \$1.1 billion in 2005–06, and 1.2 billion 2006–07 as a result of an extended drought. In 2007–08, the gross value of production was at an all time recent low of \$259 million. It is forecasted to rise to \$653 million in 2008–09 (Cotton Australia, 22 December 2008, Pers comm).

Figure 5 The rise of cotton lint yields 1962–63 to 2008–09 and some related impact factors



COTTON BALES PRODUCED

Figure 7 shows the number of cotton bales ginned in Australia since 1999–2000 season. Over 3 million bales were ginned each year from 1999–00 until 2001–02 peaking at 3.5 million bales in 2000–01. Drought conditions reduced cotton production between 2002–03 and 2003–04. The following season in 2004–05 world record yields were achieved in Australia due to ideal climatic conditions (rainfall, temperature and sunlight) and production rose to 2.9 million bales. In 2005–06 a slightly greater area was planted, but production was less than the world record yielding 2004–05 season at 2.5 million bales. Due to drought conditions, the 2006–07 cotton crop produced 1.3 million bales and the 2007–08 crop produced 507 523 bales. Increased production is forecast for 2008–09, currently 640 000 bales (Cotton Australia, 22 December 2008, pers comm.)

Tables 15 and 16 show the cotton production figures for each region where cotton was grown since 1999–2000. The Gwydir valley is the largest production valley, on average 467,163 bales, followed by the Namoi Valley, 438,916 bales, and the Border Rivers regions (Mungindi/Macintyre), 402,137 bales.

NUMBER OF COTTON GROWERS

The number of cotton growers varies each year in response to water availability and comparative crop prices of cotton and alternative crops such as sorghum and wheat. Figures 8 and 9, on page 22, show the number of cotton growers in NSW and Queensland. Whilst the Gwydir Valley is the largest cotton producing region, the number of cotton growers is significantly higher on the Darling Downs where there are 300–400 farmers usually growing a small area of cotton in rotation with other crops such as sorghum, maize and wheat. The Namoi Valley, which extends from Breeza to Walgett has around 200 growers, but grower numbers have declined due to the drought. The Macquarie valley has also had a high number of growers, but this has contracted in recent years due to the drought. In total, Cotton Australia now reports there are 800 cotton growers in Australia (Greg Kauter, Cotton Australia, pers comm., 22 December 2008).

Figure 6 Gross value of cotton produced in Australia from 1989–2009.

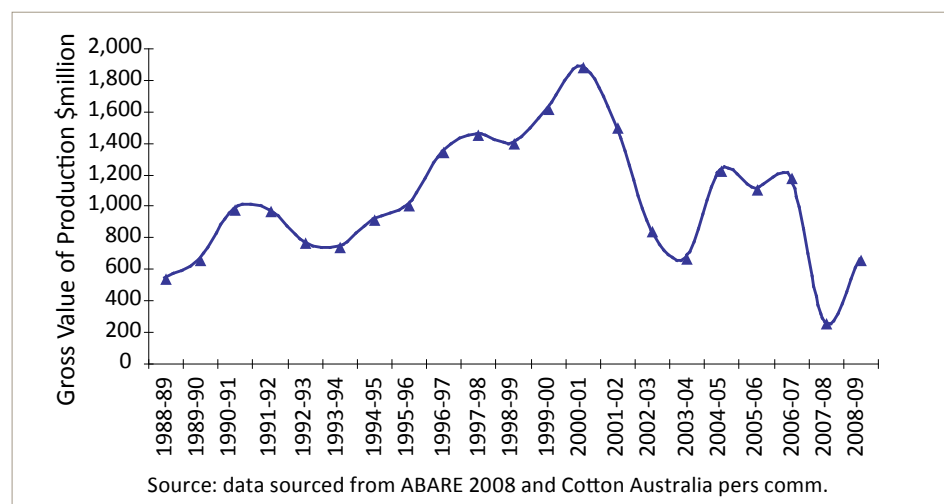
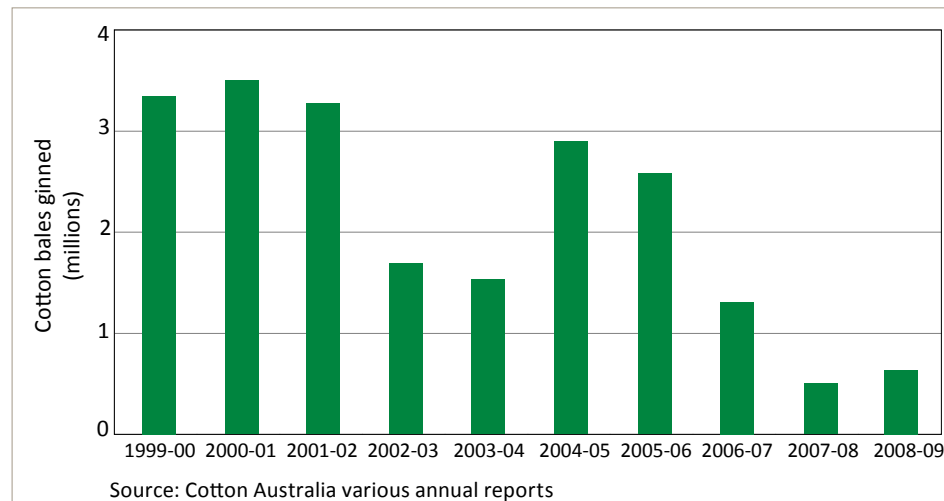


Figure 7 Cotton bales ginned in Australia for the last 10 years (1999–2009)



CONTRIBUTION OF COTTON PRODUCTION TO LOCAL GOVERNMENT REGIONS

Table 17, on the following page, shows the value of cotton production as a percentage of total agricultural production value in most local government regions in NSW and Queensland where cotton was grown. In Queensland councils earn a significant percentage of their agricultural income from cotton: Emerald (24–38%), Balonne (53–59%), Waggamba (30–35%) and the Darling Downs councils (Dalby, Wambo, Jondaryan, Pittsworth, Milmerran 20–50%). In NSW, Moree, Narrabri, Warren and Bourke shires had close to 60% their agricultural production in value from cotton up to 2001, however, in the 2006 census these proportions had fallen significantly, down to 30–40% due to water shortages. Gunnedah, Narromine and Walgett Councils had close to 30% of their agricultural production value from cotton between 1997 and 2001. Powell and Chalmers (2009) have calculated detailed figures on cotton and other industries for Moree, Narrabri, Narromine, Warren and The Darling Downs council areas.

THE WORLD COTTON SCENE

Cotton is produced in over 100 countries in the world, and five of them, China, India, Pakistan, USA and Uzbekistan, share 75% of production, 71% of area and 70% of consumption (Chaudhry 2006). The most significant recent changes in the world cotton supply have been reduced consumption in the USA, expanded production and use in China, high local consumption in Pakistan and more than 50% yield increases in India (Chaudhry 2006). The other major change has been increased production in Brazil. On average, 33–34 million hectares are planted to cotton around the world every year (Chaudhry 2006). In 2006, the USDA reported estimated world production at 114.6 million bales when Australia produced 2.5 million of these bales (Dall'Alba 2006).

Figure 10, on page 23, shows the amount of cotton produced and consumed in the world each year. World production is estimated at 23.8 million tonnes and consumption is 24.1 million tonnes for 2008–09 (ICAC 2009). World production has dropped in recent years as significant proportions of cotton area have been diverted to grain and oilseed crops for which prices were

Table 15 Number of cotton bales ginned in each NSW cotton region 2000–2008

YEAR	MACQUARIE	LOWER NAMOI	UPPER NAMOI	WALGETT	GWYDIR	BOURKE	MENINDEE MURRUMBIDGEE	LACHLAN
2007/2008	34,153	99,162	56,705	0	87,909	1,063	4,267	21,276
2006/2007	154,085	227,155	73,172	0	374,426	364	9540	57,000
2005/2006	173,681	438,008	124,244	35,000	488,634	32,124	16,124	69,212
2004/2005	88,347	400,609	129,386	35,288	504,631	122,039	8,500	55,000
2003/2004	137,198	231,150	94,307	0	193,583	6,565	0	81,447
2002/2003	251,000	345,240	67,024	0	379,630	3,074	35,279	46,993
2001/2002	473,000	435,078	89,000	60,000	825,650	66,840	49,350	87,000
2000/2001	390,000	400,000	130,000	90,000	700,000	110,000	40,000	130,000
1999/2000	370,000	420,000	190,000	90,000	650,000	93,760	40,000	100,000
Average	230,163	332,934	105,982	34,476	467,163	48,425	22,562	71,992

Source: various Cotton Australia annual reports

Table 16 Number of cotton bales ginned in each Qld cotton region and industry total 2000–2008

YEAR	MACINTYRE	MUNGINDI	ST GEORGE	DIRRANBANDI	DARLING DOWNS	DAWSON VALLEY	EMERALD	TOTAL (NSW & QLD)
2007/2008	48,000	7,599	26,308	621	79,450	14,382	26,631	507,523
2006/2007	160,885	67,849	35,736	0	92,320	29,954	41,132	1,315,032
2005/2006	333,381	177,158	155,458	40,059	338,172	56,000	116,616	2,477,255
2004/2005	499,430	233,369	187,097	100,484	344,902	47,822	146,149	2,756,905
2003/2004	131,555	29,500	97,885	7,773	415,693	44,333	67,142	1,470,989
2002/2003	223,129	39,000	35,145	0	133,592	23,330	122,708	1,582,436
2001/2002	543,381	0	119,556	50,745	287,977	46,122	146,542	3,133,699
2000/2001	450,000	150,000	190,000	155,000	300,000	62,000	209,000	3,297,000
1999/2000	425,000	100,000	185,000	180,000	312,000	60,067	150,000	3,215,827
Average	312,751	89,386	114,687	59,409	256,012	42,668	113,991	2,195,185

Source: various Cotton Australia annual reports

Figure 8 The number of cotton growers in Queensland regions from 2001-2007

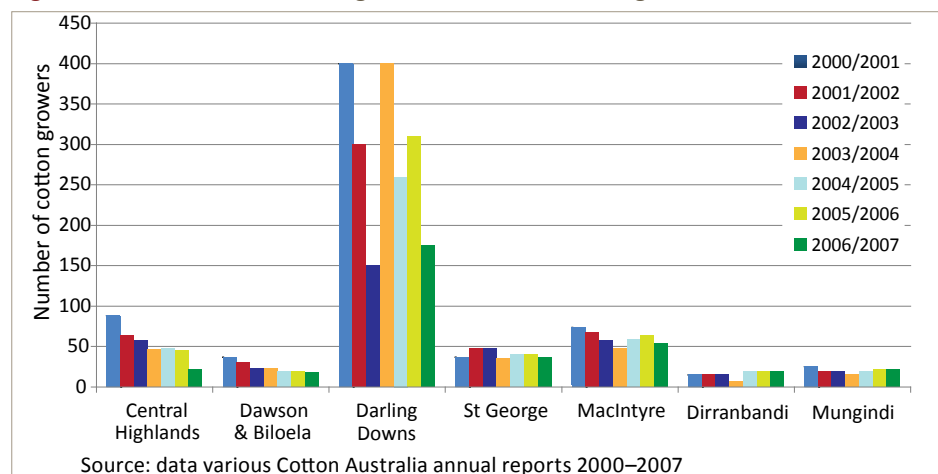


Figure 9 The number of cotton growers in NSW regions from 2001-2007

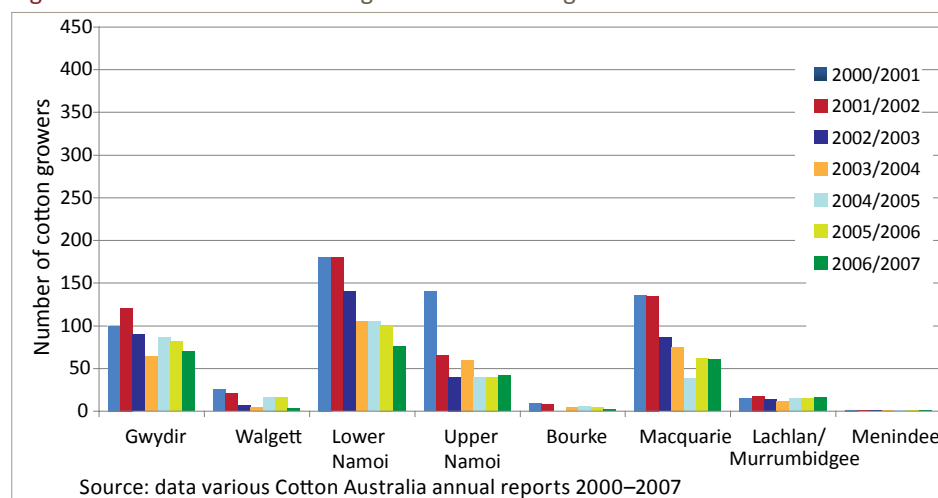


Table 17 Cotton production contribution to agricultural production in selected Local Government regions

LOCAL GOVERNMENT AREA	1997 ¹	2001 ²	2006 ³
	% OF AGRICULTURAL PRODUCTION (\$)	% OF AGRICULTURAL PRODUCTION (\$)	% OF AGRICULTURAL PRODUCTION (\$)
Emerald	37.5	23.6	
Bananna	22.2	13.7	
Balonne	53.1	59.4	
Wambo	29	25.9	
Dalby	49.4		
Jondaryan	27.3	18.7	
Pittsworth	44.2	44	
Chinchilla	8	4.8	
Milmeran	35.8	20.5	
Waggamba	30	35.2	
Moree	55	62.6	43.7
Walgett	28.6	41.8	
Gunnedah	33	26.8	
Narrabri	60.2	63.8	28.4
Narromine	26.1	37.5	34.8
Warren	49.7	57.3	44.2
Bourke	66.4	61.7	
Carathool	0.6	n/a	
Lachlan	n/a	n/a	
Darling Downs			17.6

Source: Figures compiled from data supplied by ABS from 1997 ABS Agricultural Census and 2001 Census^{1,2}; Stubbs and Powell 2008³

more attractive than cotton. The International Cotton Advisory Committee has forecast a 10% reduction in Chinese cotton mill use in 2008–09. China is the largest consumer of cotton, accounting for around 40% of world cotton mill use. World cotton production to 2020 is projected to increase to the same level of consumption of 32 million tonnes (147 million bales in 2020, Townsend 2007).

EXPORT DESTINATIONS OF AUSTRALIAN COTTON

The current major buyers of Australian cotton (in order) are China, Indonesia, Thailand, South Korea, and Japan. In particular years, China and India have been significant consumers of Australian cotton. In 1980, 68% of Australian cotton was exported to Japan. In 1994, Japan was the major export market taking 32% of the Australian crop. High costs of labour forced Japanese manufacturers to move to Indonesia, Thailand and more recently China. From 1999 Indonesia became the major destination for

Australian cotton. However, the major recent change has been the emergence of China as the world's largest market. In 2004, China took 15% of the Australian crop, whilst in 2005 this rose to 36%. It is likely that China will be Australia's most important market for the foreseeable future (Dall'Abra 2006).

COTTON PRICES

Australian cotton prices vary due to the world cotton price (in US dollars) and the Australian / US dollar exchange rate. Cotton is traded globally in US dollars. Taking into account the world cotton price and currency exchange rates, Figure 11 shows how the weekly cash price of Australian cotton to farmers has varied over the last 20 years.

Prices have ranged from \$300 / bale to \$600 /bale in the last five years. For the last two years they have hovered around \$400/ bale. Figure 11 shows between 1986 and 2008 the average cotton price was \$442/bale. The all time high in this period was

Figure 10 World production and consumption of cotton

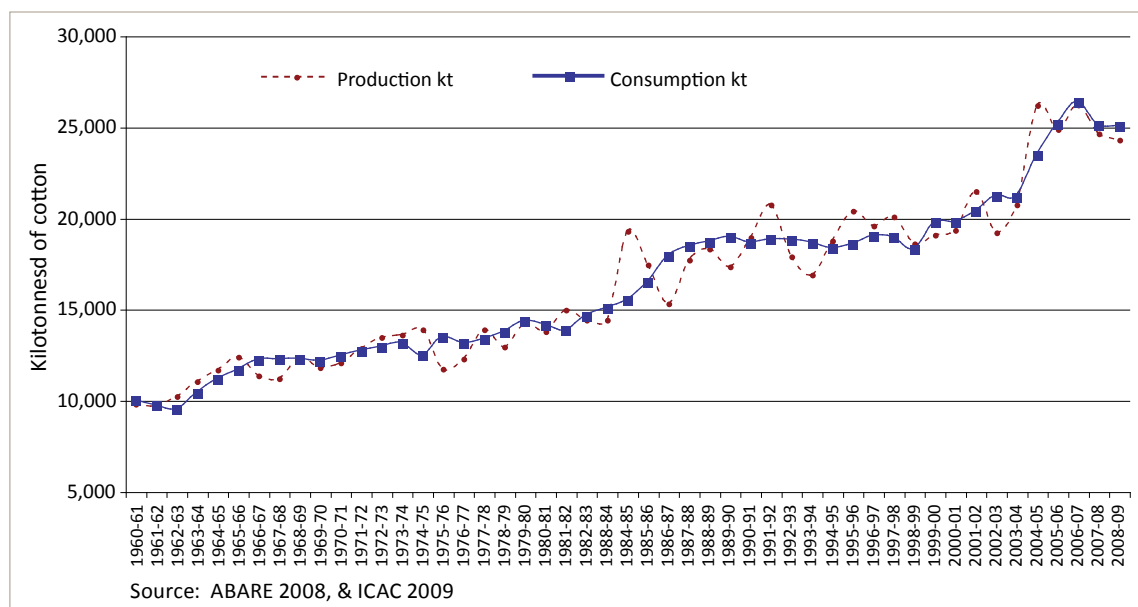
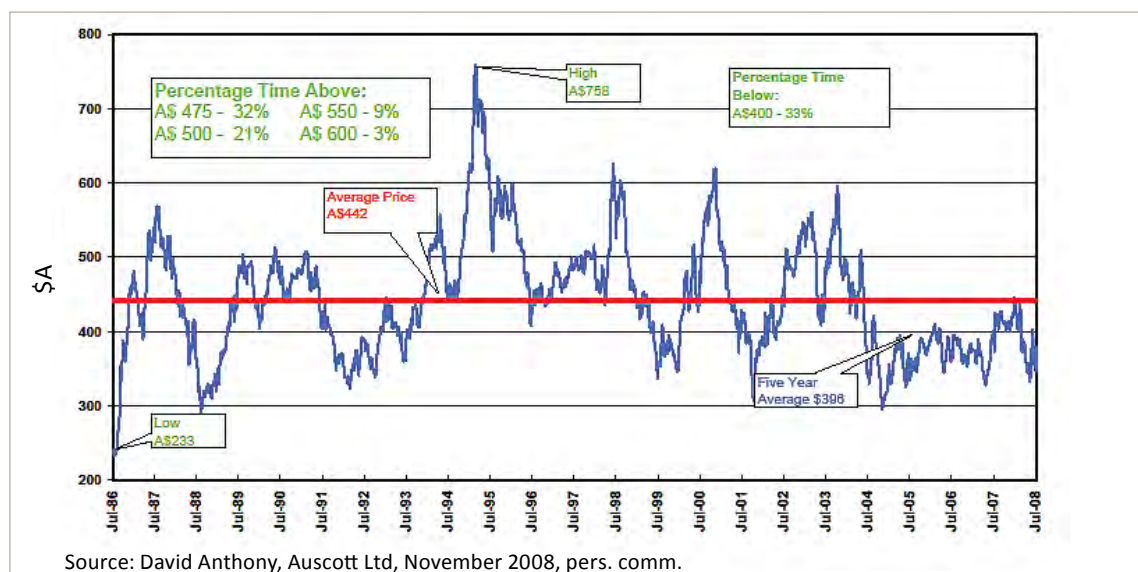


Figure 11 Weekly cash price of cotton, 1986–2008



\$758 / bale in 1995 while the all time low was \$233/bale in 1986. The five year average for the last 5 years has been \$396/bale.

Australian cotton is marketed under a competitive market system by several major cotton merchants. Cotton growers use a sophisticated range of risk management and price hedging strategies to manage price and currency fluctuations. There is no government price support in Australia.

A current risk to the Australian cotton industry is climate variability and drought. The recent drought has resulted in less production, which meant cotton buyers around the world were forced to buy cotton elsewhere to meet their needs. This provided an opportunity for other international competitors to increase their market share and means buyers may not return to the Australian market when conditions improve.

ECONOMIC RETURNS OF COTTON PRODUCTION TO COTTON GROWERS

Farmers grow cotton because they believe it is the most profitable crop for them per unit area of land and water used. Boyce Chartered Accountants have been producing an Australian cotton crop comparative analysis since 1989 to track the economic performance of cotton producers (Newnham 2006).

Figure 12 shows the total income of all growers as well as the top 20% of growers between 1989 and 2006. Total income has ranged between \$3000 and \$4000 /ha, with considerable variation due to yields and price. For example, in 2004 the drought resulted in a small area of production; however yields were good and the price was outstanding at \$550 / bale, which resulted in high incomes (\$4569/ha). The following 2005 season crop, yields were outstanding (10 bales /ha), and the price was poor (\$431/ bale), but the incomes remained high (\$4370 / ha). The top 20% of growers have higher incomes per hectare.

Operating expenses

Figure 13 shows operating expenses have increased over time. In the 2003 and 2004 years the high operating expenses were

because of the drought and growers needed to allocate costs to a smaller crop area than they normally grow. This resulted in reduced economies of scale. Costs have risen 71% from \$1750 in 1989 up to around \$3000 / ha in 2006. The top 20% of producers have lower costs.

Operating and net profit

Operating profit before interest is illustrated in Figure 14. Operating profit (income less expenses – before interest) has trended downward from the good years in the 1990s. The top producers have significantly higher profit levels. In the past years the difference between the two groups has increased.

Net profit (ie after interest costs) is also trending downwards (Figure 15). Some of the recent variation such as in 2005 is due to growers with high debt having to spread their interest over smaller crop areas due to the drought (Newnham 2006). Offsetting this deterioration in profitability has been dramatic increases in the value of land and water assets. As a result, debt to equity margins have been maintained or improved more through asset accumulation than from accumulation of farm operating profit or repayment of debt (Martyn *et al* 2006). Boyce Ltd suggest that in good water years, yield is “king” and determines profitability, while in low water years, the non direct costs that have to be apportioned over the smaller area which has a greater effect on profit than yield (Newnham 2006).

Figure 16, on page 26, shows some trends in some specific operating expenses between 1989 and 2006. Insecticides costs (chemicals and/or biotechnology crop costs) increased rapidly between 1989 and 1996. 1999 was a high pest pressure year which is the reason for the high costs that season. With the introduction of insect tolerant transgenic cotton varieties, the Cotton BMP program, a concerted integrated pest management initiative, since 1998, insecticide costs have fluctuated, but they have not continued to rise as in previous years.

Total fertiliser costs have risen from \$145 to \$270 /ha (86%), which could be due to higher yielding crops needing more

Figure 12 Total income of all growers and top 20% growers of Boyce Cotton benchmarking reports 1989–2006

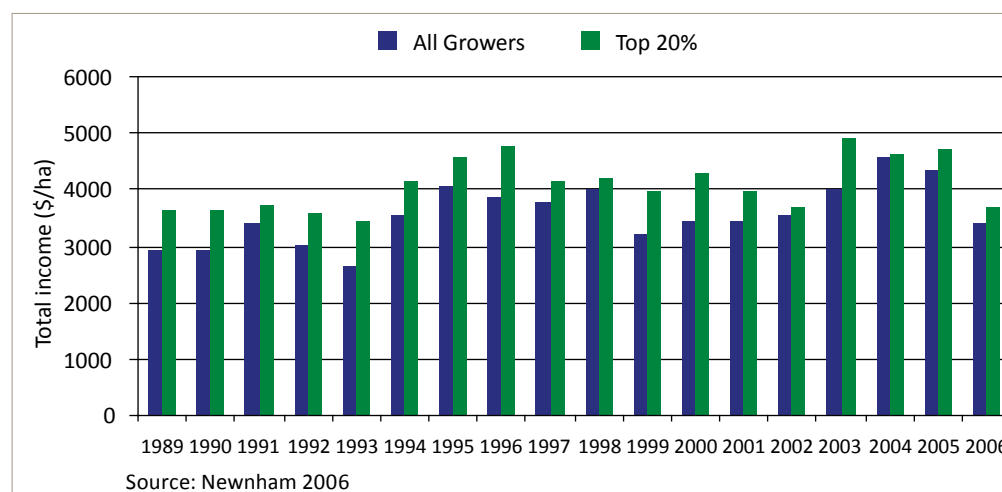


Figure 13 Operating expenses of all growers and top 20% growers of Boyce cotton benchmarking reports 1989–2006

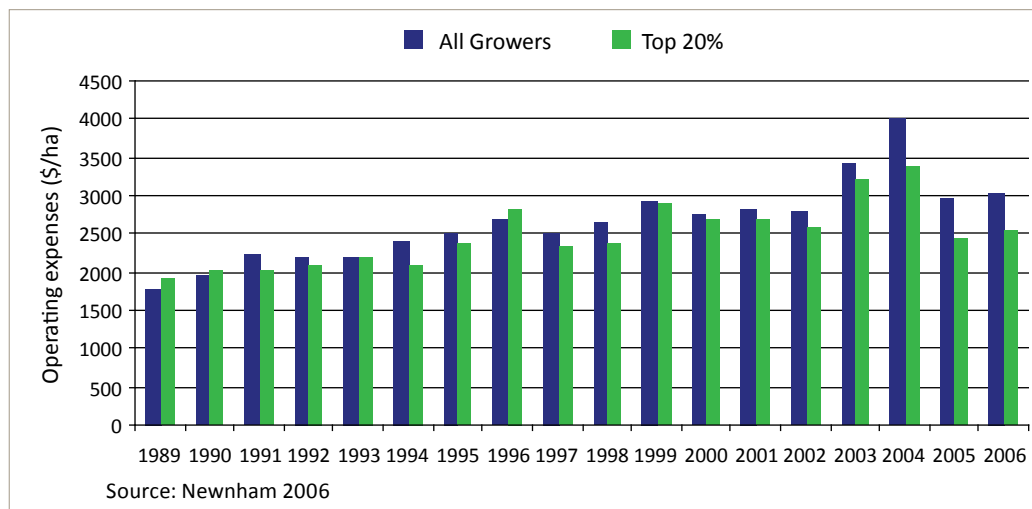


Figure 14 Operating profit before interest of all growers and top 20% growers of Boyce cotton benchmarking reports 1989–2006

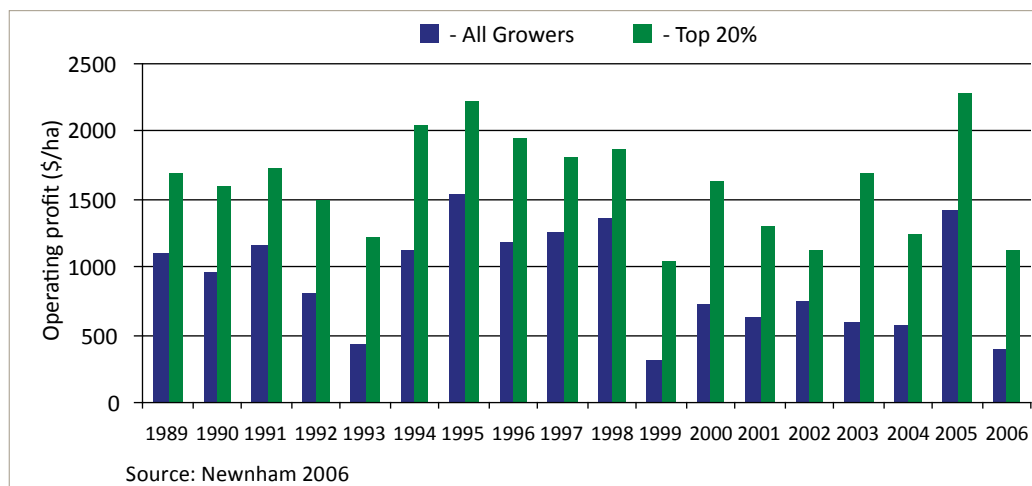
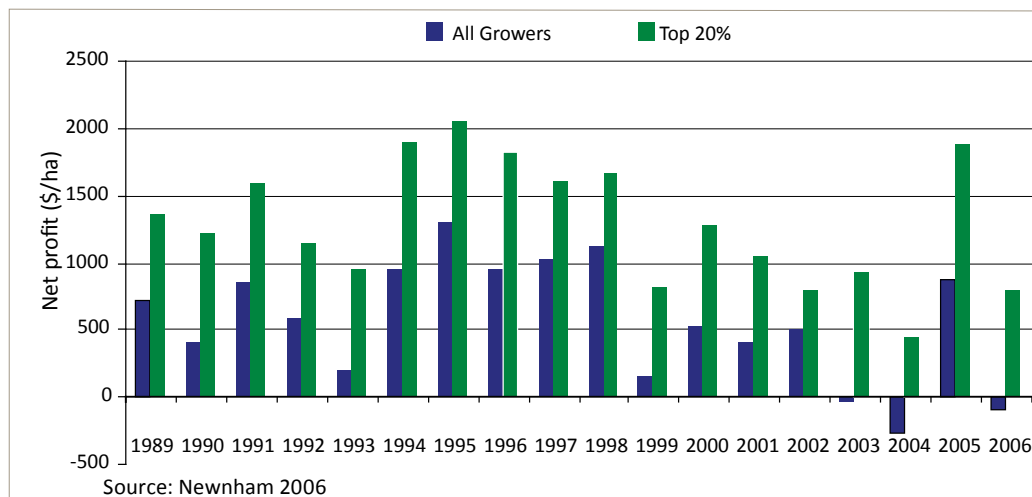


Figure 15 Net profit of all growers and top 20% growers of Boyce cotton benchmarking reports 1989–2006



fertiliser, increased cost of fertiliser or cotton fields have been farmed for longer and generally require more fertiliser. Fuel costs were flat in the 1990s, but since then they have risen due to increasing oil prices and increased pumping of water by growers to cope with the drought. Wages have risen, but not as steeply as one might expect, as better technology such as wider equipment, and biotechnology enables the more efficient use of labour. Insurance costs have also risen. There has been a dramatic increase in water costs since 2000 reflecting the need by growers to purchase water and the higher costs of water.

PROFITABILITY OF OTHER CROPS

The gross margins per hectare and per Megalitre of water for cotton, sorghum, maize and soybean, which are the most commonly grown summer irrigated crops in northern NSW and inland Queensland are shown in Figures 17 and 18. Cotton has traditionally been the most profitable of these crops on a per hectare basis and a per Megalitre of water basis; however, this gap is narrowing. This is due to rising grain prices. Similar trends are in the 2008–09 NSW DPI crop forecasts and it should be noted that these figures can vary significantly depending on commodity prices and seasonal conditions.

Figure 16 Selected operating costs for cotton production. Boyce cotton benchmarking reports 1989–2006

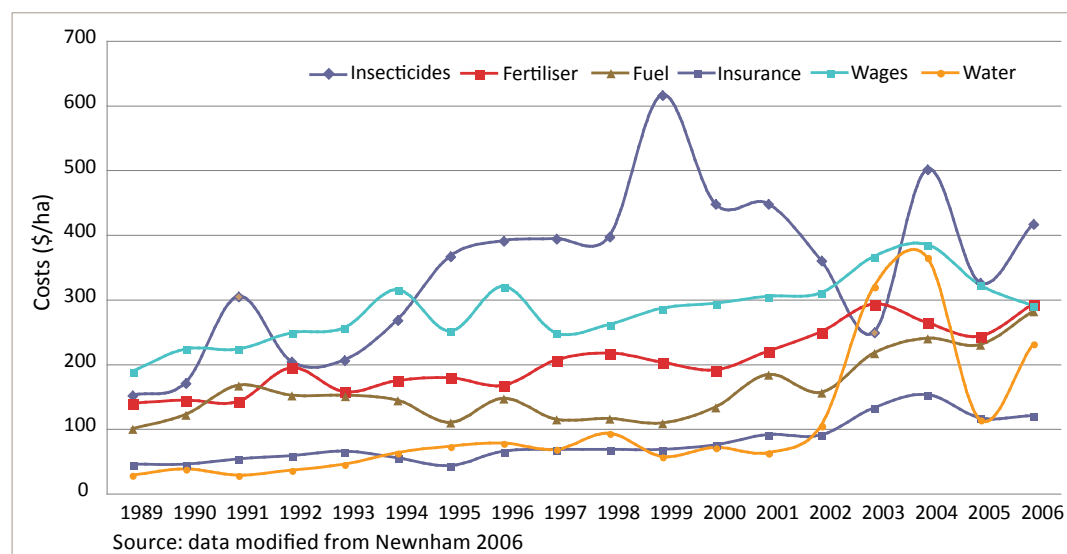
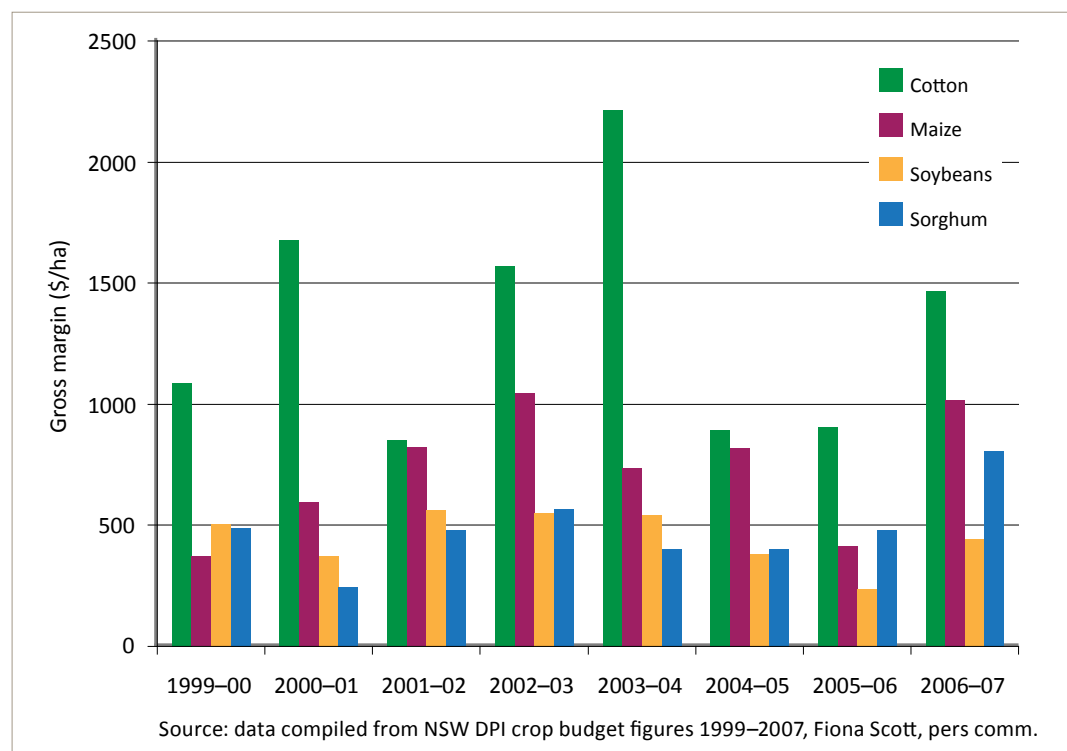


Figure 17 Irrigated summer crop gross margins per hectare 2000–2007



The decline in profitability of cotton has also led to significantly more interest by farmers in irrigated winter cereal crops. Wheat has been the most common irrigation crop in the winter, while other options include barley, chickpeas, and faba beans. In particular, there is considerable interest in high yielding winter wheat crops might be able to match cotton returns. In 2007–08, NSW DPI estimated these returns at \$564/ha or \$166/ML, while the 2008–09 forecasts for bread wheat are \$1306 /ha (\$194 / ML) and durum wheat is \$1722 /ha (\$342 /ML). These figures do compare reasonably well with cotton but they are dependent on achieving high yields, which has not been easy for many farmers. In late 2008, a wet wheat harvest led to very significant price downgrades and some farmers will be wary of this in future years when weighing up which crops to grow.

LAND AND WATER VALUES

As identified in section 3.12, most growers have obtained large increases in their net assets from increases in the value of land and water licences, rather than accumulation of profits (Newnham 2006). Land values have increased at least 100% in the last 10 years, although they are a little difficult to compare depending what infrastructure such as roads and channels are included in prices.

The value of water has increased even more significantly and by way of example, figures were obtained from conversations with several stock and station agents and long term irrigators in the Gwydir region (Figure 19). The standard water licence (972 ML) values increased from \$100,000 in 1980 to \$2,500,000 in 2008

Figure 18 Irrigated summer crop gross margins per megalitre of water 2000-2007

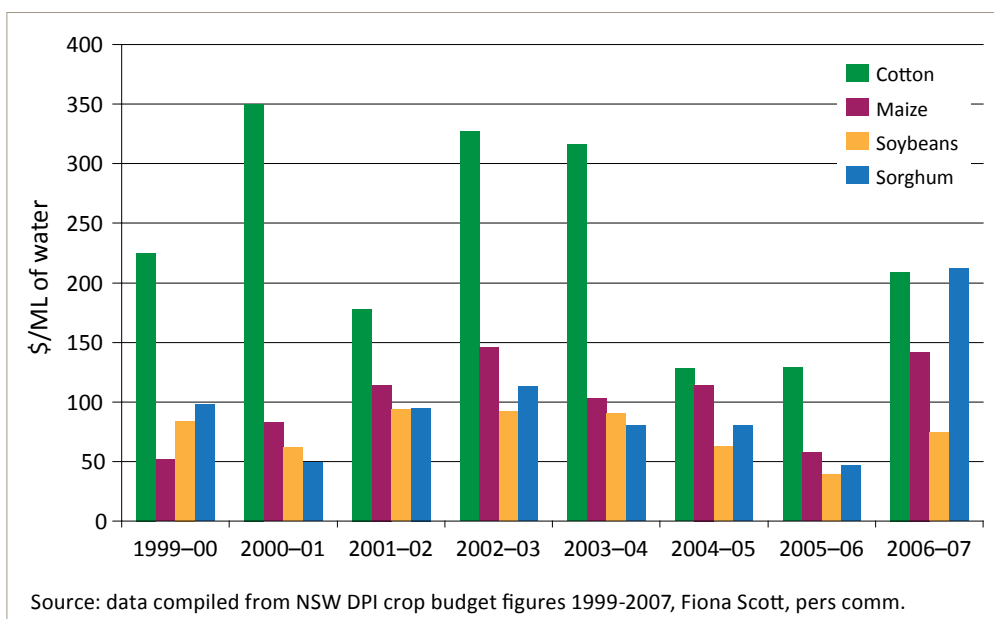
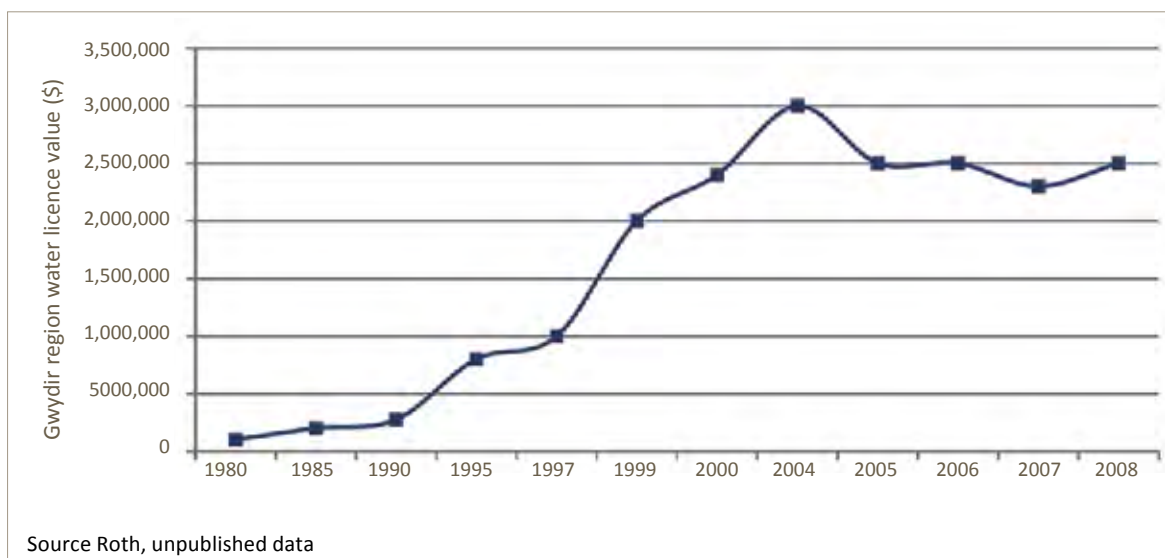


Figure 19 The value of a Gwydir valley irrigation river licence (based on 972 ML)

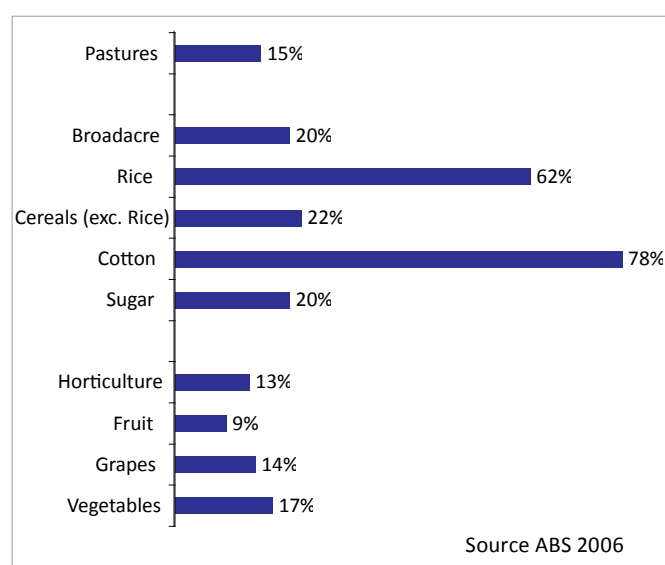


in the Gwydir valley. The peak at \$3,000,000 in 2004 was due to some special sales and conditions attached to those licences.

Market prices for permanent water sales are now being published by the Department of Environment, Water Heritage, and the Arts for all Murray Darling entitlements due to the Australian Government water reforms and the likely increased future government intervention in the market. Average prices per megalitre for a 2007–08 trade in the Gwydir region was \$2,198, Namoi \$2,050, Macquarie \$1,232 and Lachlan \$532 (GHD 2008).

The capital expenditure on irrigation for various agricultural industries is shown in Figure 20. It shows that 78% of cotton farms

Figure 20 Capital expenditure on irrigation by irrigated activity for five years to 2002-03. Percentage of farms with greater than \$100,000 expenditure



have irrigation capital expenditure in excess of \$100,000, which is significantly greater than most other irrigation industries in Australia. This is because they are usually the larger sized farms and highlights the significant capital investment made by cotton farmers.

ECONOMIC IMPORTANCE OF COTTON FIBRE QUALITY

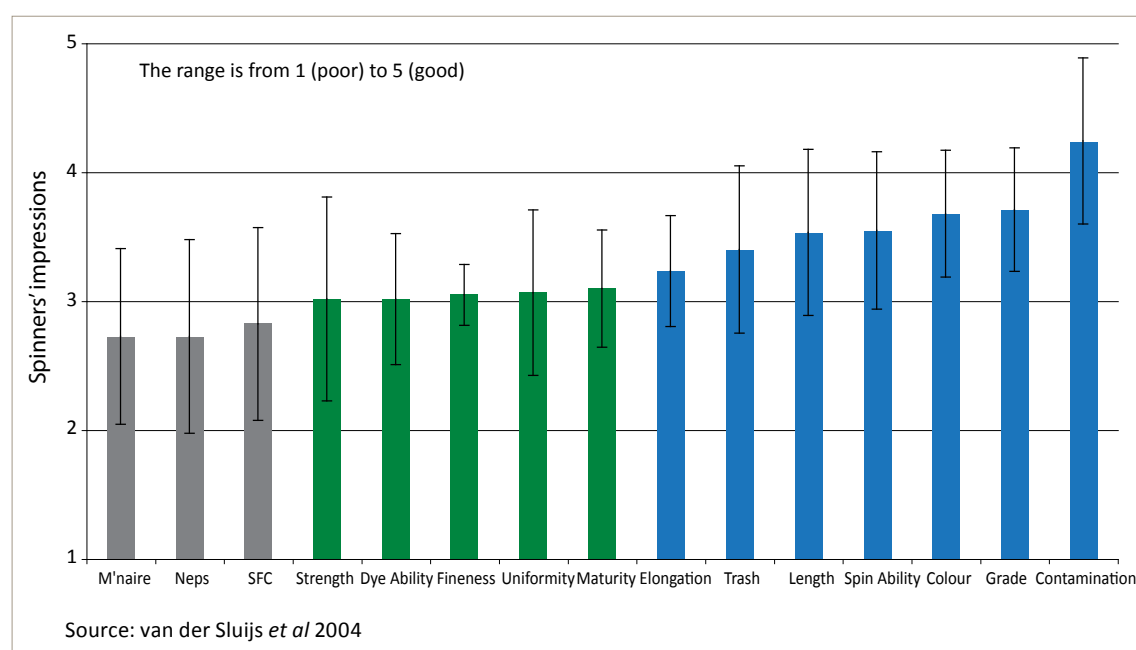
Fibre quality has a strong influence on demand and price for cotton. The Australian cotton industry operates in a large global business with significant competition from other cotton producing nations. Cotton spinners who turn the bulk cotton into a thread, need an uninterrupted supply of precise quality characteristics including long, strong and clean cotton with good fineness and maturity, low honeydew and stickiness, and no contamination at a competitive price.

Cotton fibre quality is influenced by a complex combination of cotton varieties and breeding, crop agronomy, the climate, picking and ginning. Cotton is classed by merchants and independent classers. There are a number of aspects that make up the cotton quality grade, but the most important are: colour, trash content, length, strength, and micronaire (a measure of fibre diameter and thickness). There are many other aspects of fibre quality which have been reviewed by van der Sluijs *et al* (2004), Dall'Abra (2006), Vijayshankar (2006), Constable (2007) and Bange and Constable (2006).

The quality of Australian cotton in general compares very favourably with that from other cotton producing nations (Vijayshankar 2006, Dall'Abra 2006, van der Sluijs *et al* 2004; Shimazaki 2008; Yung 2008). Australian cotton is now considered a niche product because of its high quality in the world market, but does still have its problems.

Figure 21 shows the results of a CSIRO survey of world spinning mills on their views of Australian cotton (van der Sluijs *et al* 2004). Micronaire, neps (small bundles of immature fibres) and

Figure 21 Results from CSIRO survey of world cotton mills on Australian cotton quality



short fibre content (SFC) were considered the main problems, hence their lower scores on the spinner's impressions scale. Mills complain that the short fibre content of Australian cotton is high (due to mechanical picking and ginning) compared with hand picked cotton of less developed countries, micronaire is variable and high, and the neps content was also high.

Vijayshankar (2006) drew the following broad conclusions on the quality of Australian cotton since 1992 when they commenced purchasing Australian cotton:

- Strength, maturity, reflectance, whiteness and grade showed consistent improvement.
- Effective length, uniformity ratio, longation, stickiness and honey dew remained almost consistent.
- Trash content showed wide fluctuations and needs to be improved.
- Micronaire, neps and contamination showed deterioration, and needs urgent attention.

Despite some of these negatives, Australian cotton is still highly regarded in the market place by international buyers of cotton (Shimazaki 2008; Yung 2008). Annual data on the fibre quality parameters of the Australian cotton harvest can be found on the Australian Cotton Shippers internet site (www.cottonshippers.com.au).

Figure 22 shows how the fibre length and strength of Australian cotton has improved since 1972. Australian cotton varieties bred by CSIRO have become longer and stronger.

There are many factors consumers look for when purchasing fabrics. These include comfort to wear, light weight, coolness, easy care, durable, absorption properties to keep the body dry, allergy free and of course price. The Council of Textiles Industries of Australia has more information on consumer trends and cotton (Fitzpatrick 2008).

An important trend in the world textile market is environmentally friendly cotton or "eco cotton" (Fitzpatrick 2008; Spellson

2008; Yung 2008). Organic cotton is part of the "eco cotton" theme, but cannot be produced in a cost effective manner in large quantities. Hence, the importance of cotton produced according to environmental standards with market traceability. Australia is one of the few countries where this can be produced with complete reliability and transparency (Shimazaki 2008). Sustainability reporting is a core part of this traceability and its application is discussed in Chapter 6.

SUMMARY

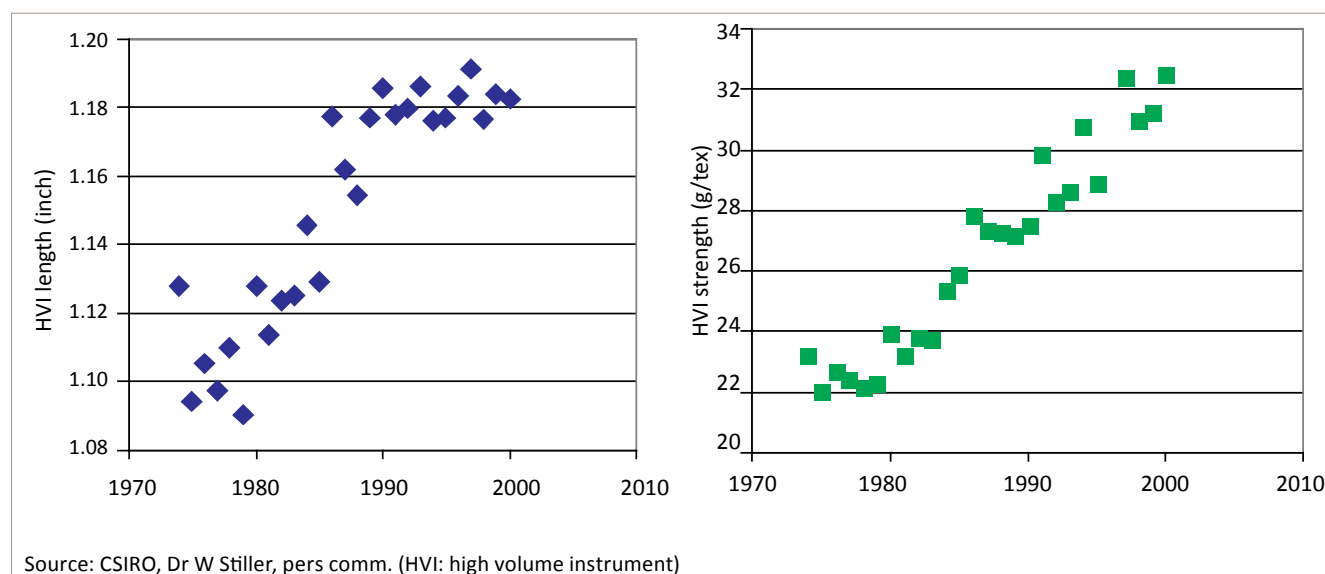
On farms where cotton is grown as the main irrigated activity the area grown is typically about 300–400 hectares of cotton. Cotton makes up the majority (about 85%) of the area of irrigated crops grown on these farms. As a result cotton makes up the largest proportion of farm income. The total farm sizes are much larger than the cotton area as they comprise areas for other crops, crop fallows, pastures, roads, irrigation channels, and native vegetation.

The area of cotton planted in Australia from 1995–96 to 1999–00 averaged 433,000 ha, while from 2000–01 to 2004–05 the average area fell to 336,000 ha. In 2007–08 the cotton area fell further to 64,885 ha, which made it the smallest crop since 1978–79. The current 2008–09 cotton crop planting area forecast is 150,800 ha, while 2009–10 should be higher again.

During the last 20 years, cotton yields have increased significantly, on average at 32.9 kg of lint per hectare per year. This is the result of improved varieties, crop agronomy and technology adoption. Australian average yields now exceed 2000 kg/lint/ha and are now the highest of any major cotton producing country in the world and are almost three times the world average and have scope to further increase.

The national gross value of production of cotton peaked at \$1.9 billion in 2000–01 and for the last few seasons has been falling due to the drought. In 2007–08, the gross value of production was at an all time recent low of \$259 million. It is forecast to rise to \$653 million in 2008–09.

Figure 22 Improvements in fibre length and strength of Australian cotton 1972–2007



The number of cotton bales produced follows a similar trend, peaking at 3.5 million bales in 2000–01. Due to drought conditions, the 2006–07 cotton crop produced 1.3 million bales and the 2007–08 crop produced 507,523 bales. Increased production is forecast for 2008–09, which is currently estimated at 640,000 bales.

The number of cotton growers have also followed a similar trend, and Cotton Australia now reports there are 800 cotton growers in Australia. The Darling Downs region has the largest number of cotton growers (300–400); however the Gwydir, Namoi and Border Rivers regions produce the most cotton from a smaller number of much larger farms.

Australian cotton is highly regarded in the market place by international buyers of cotton and is considered a niche product because of its high quality. It does still have aspects to improve, which include the short fibre content, the micronaire (fibre thickness) is variable and high, and the neps (small bundles of immature fibres) content is also high.

The area of cotton grown each year varies and is largely driven by water availability and price. For the last 20 years, cotton has been the most profitable crop to grow per unit of water and land. Financial returns for cotton production are about \$4000 / ha of income, from expenditure of \$3000–\$3500, resulting in a net profit before interest of \$500–\$1000/ha. Profitability per hectare is falling, although is still better than most other alternative crops. The net price per bale received by growers is decreasing and for the last five years has averaged \$396/ bale.

Insecticides (chemicals and/or biotechnology) are the major cost. Fertiliser, fuel, wages, insurance costs have also risen. There has been a dramatic increase in water costs.

Cotton is a major source of regional economic activity where it is grown. In the local government regions where it is grown, cotton usually makes up 30–60% the gross value of all agriculture in the shire. It is a high input crop, so the economic multipliers are high in local economies.

In terms of economic sustainability, the major threats to cotton production are the availability of water, rising costs of fuel and fertiliser, labour shortages, high pest management costs, and the falling price of cotton due to high production levels from other countries.

The next chapter will review environmental indicators of sustainability.

4 ENVIRONMENTAL INDICATORS OF THE AUSTRALIAN COTTON INDUSTRY

INTRODUCTION

This chapter compiles information related to environmental indicators for the Australian cotton industry. It includes coverage of soils and farming systems, salinity, water use and quality, natural resources, biodiversity, native vegetation, riparian land management, weeds, insects, diseases, pesticide use, pesticide resistance, and greenhouse emissions.

RECENT SOIL AND FARMING SYSTEMS SUSTAINABILITY TRENDS

Australian soils are often described as ancient highly weathered and infertile. Cotton is grown on floodplains where the soils are younger and more fertile than most Australian soils. The major soil types on which cotton is grown are grey, brown and black Vertosols (~75%), Chromosols, Sodosols and Dermosols (15%) (McKenzie *et al* 2003). The vertosols soils have high clay contents (40–80 g/100g) and strong shrink-swell capacities, but are frequently sodic at depth (Hulugalle and Scott 2008). They are commonly known as cracking clay soils due to the cracks that appear as the soils dry. This section outlines trends in soil health sustainability. Detailed soil management procedures are described in the Australian cotton industry manuals known as SOILpak (McKenzie 1990) and NUTRIpak (Rochester 2001).

Soil structure

Soil structure is affected by soil texture, clay mineralogy, organic matter, soil biota, as well as management such as compaction and tillage. Reduced soil structure was one of the first soil management issues that plagued the cotton industry. Soil structure is very important for water management of irrigated cotton. It strongly influences plant available water, water holding capacity and water infiltration rates. By way of example, an on-farm trial found that the plant available water was reduced for the following cotton crop by 41% after a wet cotton harvest (Roth and Cull 1991). This meant the interval between irrigations was reduced from 12 days to 8 days for the following cotton crop.

There were large decreases in cotton yield following harvest, tillage and land preparation under wet conditions during the early stages of commercial cotton production in Australia in the late 1960s and early 1970s. After the wet seasons of the late 1980s it was apparent that soil compaction due to wet land preparation and harvest was still causing serious problems. This led to a number of research investigations and the development of the first edition of a soil management manual known as SOILpak™ in 1990. In 1998, after another wet winter, the third edition of SOILpak™ with an additional

smaller paddock friendly ute guide and video was released. Soil management techniques to prevent or reduce compaction were delivered to cotton growers with a large extension program using soil pits and field days that markedly improved soil structure management and cotton yields.

Plate 1 shows an example of the impact of tractor wheel traffic compaction that increased soil bulk density, decreased plant height, dry matter production and consequently reduced yield. Similar results were published by McGarry (1990).

Controlled traffic cotton farming systems are used by most cotton growers to reduce compaction by driving on permanent wheel tracks as well as retaining permanent seed beds. Permanent beds were introduced in the mid 1980s (McKenzie *et al* 2003). McGarry (1995) reported 80–90% of cotton growers used permanent beds. Controlled traffic farming systems with satellite guidance systems have been widely adopted on cotton and grain farms. Conservation farming techniques such as stubble retention, and reduced tillage have also been adopted in the last decade. Stubble burning was a commonly used management tactic in the 1970s and 1980s. It is now very rare for a cotton grower to rake and burn stubble and is only done to overcome a specific problem, usually a plant disease. Shaw (2005) found 97% of farmers incorporated their stubble rather than burn it.

The heavy clay nature of most cotton soils means they are prone to waterlogging if not managed correctly and crop yield losses can be significant. Waterlogging is a process that interacts strongly with the chemistry and biology of soil (McKenzie 2007). Excess irrigation water or rain causes waterlogging that is exacerbated by soil compaction, soil dispersion from sodicity and slaking from a lack of organic matter. Problems associated with waterlogging include the accumulation of manganese to toxic levels, increased root diseases, greater nitrogen fertiliser loss through denitrification, while other soil biota such as earth worms cannot thrive. A number of investigations into waterlogging have been undertaken. Hodgson and MacLeod (1988) looked at the



The effect of wheel traffic (left) on cotton growth and yield compared to an adjacent non-wheel track row (right)

application of foliar fertilisers. Bange *et al* (2004) examined the growth and yield response, while Conaty *et al* (2006) investigated genetic variation of cotton cultivars to waterlogged conditions.

At the farm level it is possible for growers to monitor their soil structure sustainability using some of the Soilpak methods, notes from soil pits, or by recording plant available water deficits data from soil moisture probes and monitoring if they change over time. Scientists can monitor soil bulk density or use a soil penetrometer, but this is not practical for farmers.

At an industry scale, it is much more difficult to monitor soil structure trends mostly because there is no data capture system and many of the soil structure observations are subjective. The cotton industry benchmark surveys have some quantitative industry wide data related to soil structure. The 1996–97 benchmarking survey found most growers used visual and crop condition (evidence of right angled roots), while 44% were using soil pits (CRDC 2000). The 1999–2000 benchmarking survey also found 65% of growers monitored soil compaction when 44% of growers used soil pits, 44% used moisture probes, while the majority 79% looked for right angle roots (CRDC 2002). The 2005–06 benchmark survey found 66% of growers monitor soil structure; 83% of these growers used a visual inspection of fields, 69% used the crop condition, 32% used soil pits and 16% used a field test (soil core or soil moisture probe data) (CCA 2007a). An alternative approach for monitoring industry wide trends is proposed in Chapter 6 by using the BMP rankings.

Soil salinity

Salinity is the presence of soluble salts in the landscape and soil solution. Globally, salinity is a major sustainability problem where cotton is grown, for example, in India, Uzbekistan, China, Pakistan and USA. Soil salinisation has also been recognised as a potentially threatening problem in the Murray Darling Basin. In irrigated cotton, soil salinisation occurs as a consequence of excessive deep drainage, which can create rising water tables, or through the direct application of saline or sodic water. Cotton is one of the most tolerant field crops of salinity, reportedly able to tolerate soil root zone salinity around 7.5 dS/m, but is more susceptible as a seedling (Jessop *et al* 1993). As a seedling, impacts on cotton yields can occur around 1.5 dS/m (Maas and Chapman 2005).

To ensure salinity does not become a major problem for the cotton industry the Cotton CRC, CRDC, Natural Heritage Trust and The University of Sydney have worked collectively to map the soils where cotton is grown in Australia. This has identified areas that are more susceptible to salinity. A web-based Geographic Information System contains digital biophysical data (e.g. soil, water and hydrological properties) in seven irrigated cotton growing areas (i.e. Toobeah, Ashley, Wee Waa and Gunnedah, Trangie and Warren & Bourke) located in five catchments (Macintyre, Gwydir, Namoi, Macquarie & Darling) (Triantafyllis 2007). This data was also compiled onto a CD for future reference (The University of Sydney 2004).

At the farm scale, farmer's soil tests can be used to monitor salinity trends. Most standard soil tests include sodium, chloride and other cations. An example of this is shown in the case study

at the end of this chapter. An alternative approach is the use of electromagnetic surveys. Figure 23 shows the mapping of saline subsurface soils at Bourke. There are many growers now undertaking EM surveys to improve their irrigation and soil management.

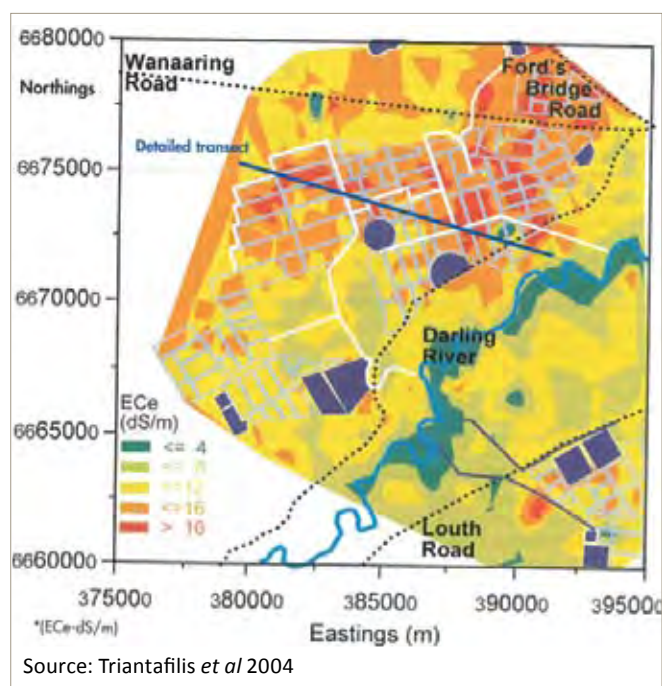
At the industry scale, salinity was noted by less than 5% of growers in the 1996–97 cotton industry benchmarking survey (CRDC 2000a). The 1999–00 benchmarking survey found 12 % of growers believed they had a problem with salinity with most cases in the Macintyre, Macquarie and Emerald. Bourke was not included (CRDC 2002). The 2005–06 benchmarking survey found 48% of growers measure soil salinity (CCA 2007a). The 2006–07 benchmarking report found a similar figure of 52% of cotton growers were monitoring soil salinity (WRI 2007a).

Soil sodicity

Soil sodicity refers to the proportion of sodium cations held on the clay particles surface and is of greater concern to most cotton growers than soil salinity where the sodium is in the soil solution. Much of Australia's cotton crop is grown on soils of high subsoil sodicity and some soils also have surface layers that are considered sodic (exchangeable sodium percentage (ESP) > 5%) (McKenzie 1990). The high sodium levels cause soil dispersion and hence create soil structure problems.

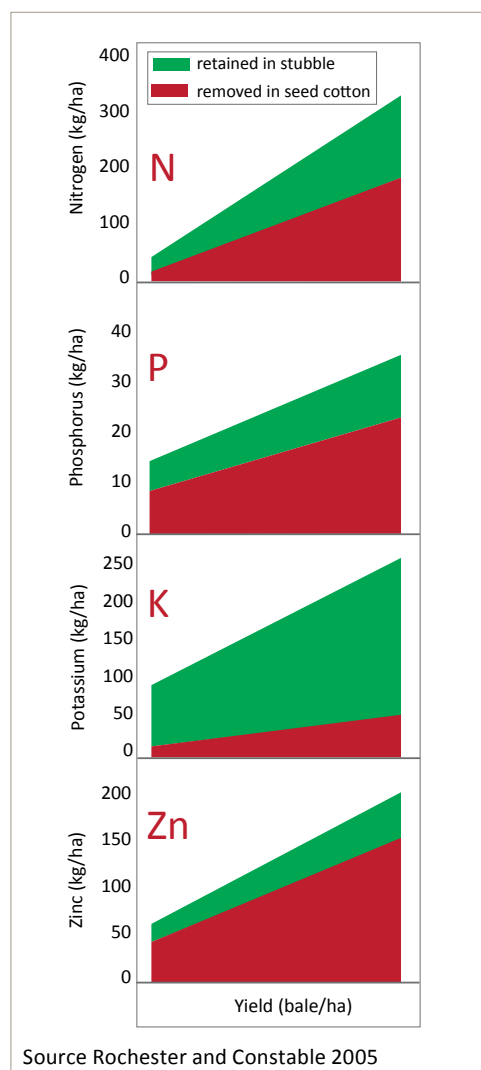
The effect of sodicity in relation to its negative effects on soil structure have been documented by Vervoot *et al* (2003) who found decreased soil hydraulic conductivity and increased soil bulk density with increased soil exchangeable sodium percentage. Sodium changes the chemistry of the soil solution, which alters the availability of nutrients to the plant. As the level of sodium in the soil increases, there is a corresponding decrease

Figure 23 Distribution of saline subsurface material between 6–12 metres at Bourke



in the uptake of phosphorus and potassium by the cotton plant, with these nutrients reaching deficient levels as the crop matures (Dodd 2004). The amelioration required to reduce sodicity impacts continues to be the focus of many current industry funded research projects in the cotton and grains industries.

Figure 24 The proportions of crop nutrients removed in seed cotton (red) or returned to the soil in leaf and stubble after harvest (green)



At the individual farm scale, standard soil tests can be used to monitor sodicity levels trends by recording the exchangeable sodium percentage. An example of this is shown in the case study at the end of this chapter. At the industry scale, the cotton industry benchmarking survey 2005–06 found 57% of growers measure soil sodicity (CCA 2007a). The 2006–07 report found a similar figure of 52% of growers monitoring sodicity (WRI 2007a). The BMP rankings discussed in Chapter 6 can also be used to monitor management trends.

Crop nutrition and fertiliser rates

The principles of cotton crop nutrition were summarised by Hearn (1981). There has been a steady stream of cotton nutrition investigations into nitrogen (Constable and Rochester 1988; Rochester and Peoples 2005; Rochester 2008), phosphorus (Dorahy *et al* 2004; Dodd (2004), potassium (Wright 1999) and the micronutrients (Constable *et al* 1988).

In recent years there have been large increases in cotton yields. The amount of nutrients removed as cotton seed increases with crop yield. This is leading to elevated nutrient use and removal and poses challenges from a sustainability perspective. For a 10 bale/ha cotton crop, about 60% of the phosphorus and zinc taken up are removed in the seed, about 50% of the nitrogen is removed, while only 15% of the potassium is removed (Figure 24). Nutrients not removed in the leaf and stalk material are recycled in the soil after cotton picking.

The simplest indicators of fertiliser use are the rates applied per hectare. Nitrogen, phosphorus, potassium and zinc are the most commonly applied fertilisers. Table 18 summarises trends in fertiliser use. Overall, the use of fertiliser is increasing. The pre-season use of solid fertilisers such as urea is increasing while the pre-season use of anhydrous ammonia gas is decreasing. The addition of fertiliser during the season is increasing as growers strive to optimise input levels. Phosphorus fertiliser use has increased and potassium fertiliser use has doubled between 2001 and 2006. Zinc fertiliser use has remained relatively constant.

Nitrogen is the main nutrient that limits plant growth and is currently typically applied at rates 180–220 kg/ha and in some cases 300 kg/ha. Figure 25, on the following page, shows how nitrogen fertiliser rates have increased from an average 125 kg/N/ha in 1980, 150 kg/N/ha in 1990, 180 kg/N/ha in 2000 and 210 kg/N/ha 2008–09. Figure 25 also shows that some cotton producers are applying almost 300 kg/N/ha and the economic sustainability

Table 18 Trends in fertiliser use 2001–2007

FERTILISER	2001*	2006*	2007**	TREND
Pre season nitrogen - solid fertiliser (kg/N/ha)	80	87	101	↑
Pre season nitrogen - gas fertiliser (kg/N/ha)	78	71	60	↓
In season nitrogen – solid fertiliser (kg/N/ha)	17	29	60	↑
In season nitrogen – gas fertiliser (kg/N/ha)	8	14	18	↑
Pre season phosphorus fertiliser (kg/P/ha)	23	30	35	↑
In season phosphorus fertiliser (kg/P/ha)	2	3	2	↑
Pre season potassium fertiliser (kg/K/ha)	8	16	24	↑
In season potassium fertiliser (kg/K/ha)	0	2	4	↑
Zinc fertiliser (kg/Zn/ha)	5	5	5	↔

Source: data modified from CRDC 2007*, WRI 2007a**

of this practice when fertiliser prices are high is questionable. Higher fertiliser rates do not mean that high yields are unsustainable, however the sustainability of some current nitrogen practices is questionable.

Nitrogen losses on average are 30% of the nitrogen fertiliser applied to irrigated cotton (Rochester 2008) and are not well understood by individual growers. Crop nitrogen use efficiency, which describes how well crops convert the nitrogen they accumulate into yield is defined as lint yield (kg/ha) divided by crop nitrogen uptake (kg/ha). Nitrogen use efficiency was measured in 34 crops in five cotton growing valleys during 2006–07 (Rochester *et al* 2007). They found low nitrogen use efficiency values in 50% of the crops, which on averaged had an excess of 40kg/N/ha applied to them. This indicates there is considerable scope to reduce nitrogen use without impacting negatively on yields.

An easier and alternative approach can be achieved by analysing seed sampled from cotton modules at harvest time in the field. This is much quicker, simpler and less expensive than measuring crop N uptake at crop maturity. Seed nitrogen percentage is closely related to crop nitrogen use efficiency (Rochester 2008).

A list of 30 cotton growers' fertiliser regimes can be found in Shaw (2005). In 10 years time, it could be interesting to review any changes to these fertiliser practices as a case study.

The use of soil testing

Cotton growers have used soil testing for many years although their use has been sporadic. Data from the 2005–06 season found the majority (89%) use soil tests augmented with field history knowledge and other methods while 49% were using leaf/petiole tests (CCA 2007a). The 2005–06 survey found 35% of growers soil test every year, while 41% test with no set strategy

and 24% soil test before every cotton crop (CCA 2007a). This trend is supported by the following season survey that found in the 2006–07 season almost all (95%) respondents indicated they used soil testing, but is not possible to determine how often it was done (WRI 2007a).

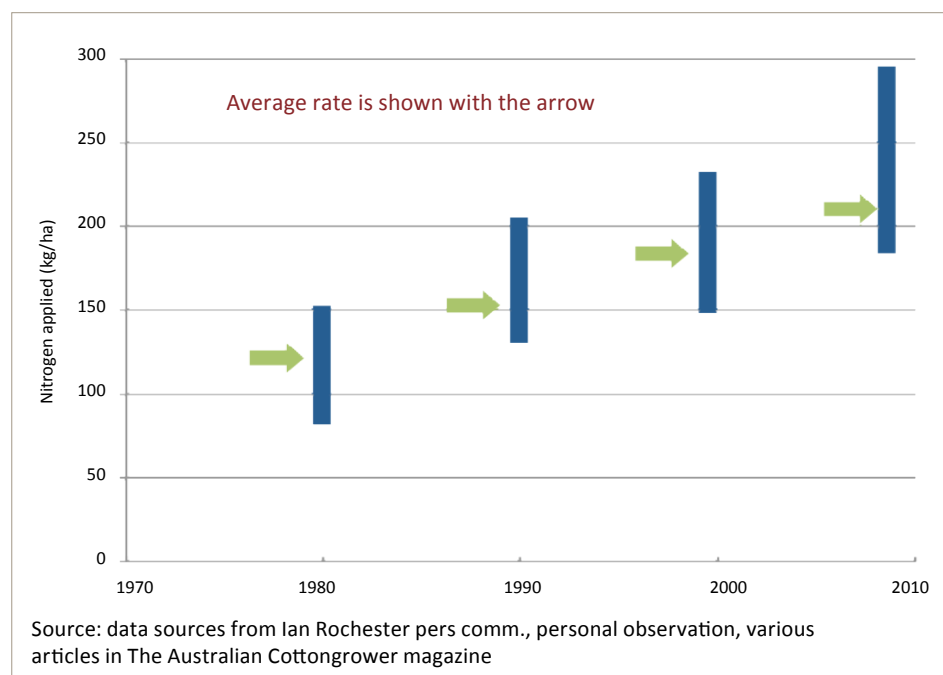
Greenhouse gas emissions

Agriculture produced 16% of Australia's greenhouse emissions, 90.1 million tonnes CO₂e of which 69% comes from livestock (Australian Government 2008). It was estimated that cotton produced 0.2 million tonnes of CO₂e in 2005, which is 0.3% of total agricultural emissions (NLWRA 2008) and the major source of its emissions are from fertiliser (CRDC 2008).

The principal sources of greenhouse gas emissions on mixed cotton farming enterprises include carbon dioxide (CO₂), methane and nitrous oxide. The source of carbon dioxide is from decomposition of crop residues and the combustion of fuels used to operate machinery. The source of methane is from prolonged waterlogging periods and nitrous oxide (N₂O) that can be produced during transformation of fertiliser nitrogen applied to soils. Cotton crops also store carbon in short term sinks in the soil like other crops, but unlike other crops, cotton lint which is harvested stores carbon for a number of years. The cotton industry should explore this unique feature as part of the carbon emissions policy development currently underway.

A case study of the annual estimated greenhouse gas emissions from a typical 416 ha Darling Downs farm, which included cotton, wheat, sorghum and some livestock found the farm produced 400 CO₂e (tonnes) per annum (Grace 2008). When the model includes the amount for cotton lint produced as a carbon sink, the estimated carbon sequestration on the farm became negative (ie a carbon sink rather than producer). However, current

Figure 25 The range in nitrogen fertiliser rates on Australian cotton fields between 1980 and 2009



government policy doesn't recognize cotton lint as a carbon sink. On line greenhouse gas inventory tools for cotton and mixed farming properties are available on line at www.isr.qut.edu.au.

The cotton industry has also undertaken some pilot energy audits to better understand its greenhouse emissions. These audits found that pumping irrigation water is the highest energy user, typically 40–60%, followed by crop harvesting 20% (Ballie and Chen 2008). They found the seven pilot farms in their study produced 275 – 1404 CO₂ e /ha of greenhouse gases.

Rhiannon Smith, a PhD student at UNE, is looking at ecosystem services on cotton farms. Her project intends to produce a more accurate carbon model for native vegetation, specifically coolabah trees commonly found on cotton farms. Growers can use this information to estimate the carbon stored in their own vegetation and soils and calculate the amount of vegetation under different management required to sequester enough carbon to make their operations carbon neutral, or accumulate carbon that may be able to be traded in the future. Her project and the tools should be completed by 2010.

The proposed new carbon emissions trading scheme by the Australian Government may require farmers and other industries to calculate and monitor greenhouse emissions. The current policy is that agriculture will be exempt; however, the cotton industry will need to improve its monitoring and calculation procedures to inform future policy development.

Crop rotations

Every cotton farm produces other commodities, most commonly grain crops. Cotton production rotation systems have ranged from growing continuous cotton, to the use of winter cereal crops, fallowing and more recently legume crops such as faba beans and vetch. Corn, sorghum, soybeans and sunflowers are other common summer rotation crops.

Table 19 shows the most common rotation frequency over the last decade has been one year cotton, one year either fallow or an alternative crop. This is followed by two years of cotton. There is also a trend that 8–22% of farmers grow cotton for more than six years in a row. There are a number of reasons for these trends and the large amount of variability in the data. These in-

clude cotton prices, water availability and the price of alternative crops such as wheat.

In 1992, wheat was the preferred rotation crop of 72% of cotton growers with barley, field peas, faba beans, safflower and soybeans the other most common rotation crops (Cooper 1992). In 1997, wheat was the most common rotation crop grown by 41% of growers with sorghum, barley and chickpeas the other most common rotation crops (Hickman *et al* 1998). In the 2005–06 cotton season wheat was still the preferred rotation crop (71%) (CCA 2007).

Rotation crops are grown to improve soil structure, provide organic matter, break cotton disease cycles, help manage weeds and provide nitrogen when legume crops are grown. With the soft commodity boom between 2006–2008 and subsequent high cereal prices there has been increased areas planted to fully irrigated high yielding wheat, whereas previously the wheat was grown on relatively low inputs and usually only opportunistic irrigation, if any.

Long term trials are valuable repositories of information regarding the sustainability of agricultural practices. At Rothamsted in the United Kingdom long term cereal trials have been running for over 160 years. Some of the oldest trials in Australia include a pasture trial at Rutherglen which was established in 1913 and cropping trials at Longerenong (1917) and the Waite Institute (1925) (Norton 2007).

There have been some long term farming system trials in the vicinity of the northern NSW and SE Queensland cotton growing regions. Norton *et al* (1995) provided an update of the longest running crop rotation experiment in the summer rainfall regions of Australia at Glen Innes. Felton *et al* (1995) summarised a series of cereal crop trials in north western NSW from 1980, which have continued until a few years ago, while Thompson *et al* (1995) reported on a 20 year cropping trial at Warwick. Hutchinson *et al* (1995) reports the results of a 30 year study of pastures in the New England, which highlighted amongst other variables the influence of Australia variable climate. Unfortunately many of these long term research trials are now being terminated due to funding constraints.

The cotton industry has conducted three medium term farming systems trials from 1993–2005 with sites at Warren NSW, Merah North NSW and Warra Qld. Results from these experiments have been summarised by Hulugalle and Scott (2008). A review of cotton rotation experiments between 1970 to 2006 by Hulugalle and Scott (2008) found soil organic carbon in most locations has decreased with time despite frequent sowing of rotation crops. They concluded that 2–3kg/m² per year of dry matter needs to be returned to the soil to maintain or increase soil organic carbon, whereas most cotton based cropping systems typically return 0.8 – 1.2 kg/m² per year. In Figure 26, on the following page, an example is shown in 2b, where a decrease in carbon levels between 1994 and 2001 was followed by an increase. The cropping sequence from 2000–2002 included irrigated and fertilized wheat, which was in turn followed by irrigated sorghum. These cereal crops returned 2.5 kg/m² of organic matter and the cotton return was 0.3 kg/m². Other crops like vetch can return high levels of crop residues (Rochester and Peoples 2005).

Table 19 Crop rotations of cotton growers 1997–2007

COTTON PRODUCTION FREQUENCY	1997* (%)	2000** (%)	2006*** (%)	2007**** (%)
< 1 year	4	9	19	3
1 year cotton	42	22	36	28
2 years cotton	24	17	20	10
3 years cotton	9	15	6	6
4 years cotton	6	6	6	7
5 years cotton	2	6	2	8
6 years cotton	n/a	3	2	4
> 6 years cotton	12	18	8	22

Source: Modified from CRDC 2000a*, CRDC 2000a**, CCA 2007a***, WRI 2007a****

Other causes for soil organic carbon decline can include tillage, stubble burning, and waterlogging. While stubble retention is good for soil organic carbon levels, it does create problems with irrigating, machinery operations and herbicide applications.

In general, conclusions from rotation trials found the lowest average lint yields per hectare were with cotton monocultures. Cotton wheat systems generally returned higher average gross margins/ML of water where water is the limiting resource as opposed to land. Recently, the addition of vetch to the cotton wheat system has further improved average yields and profitability. These results are all highly season (driven by water availability) and price dependent.

In future, it is likely that there will be increased use of more complex rotations in response to the global food demand and market forces. Legume crops may become more widely used if fertiliser prices continue to increase. It is likely other crops such as mustards for biofumigation purposes and greater amounts of corn and sorghum will also be grown as bio energy crops.

Soil biology

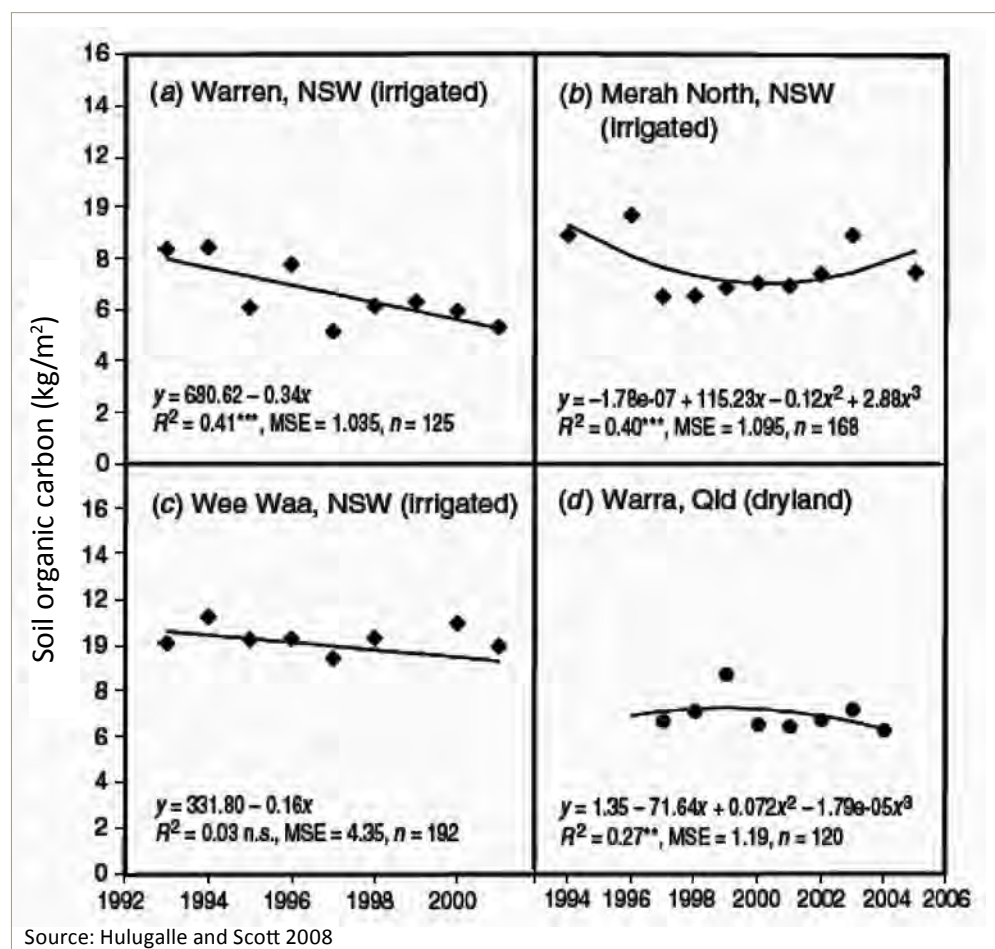
Soil biological functions play a critical role in the sustainability of cotton production. Greater interest is now being shown in soil biology by the cotton industry. A review of cotton soil biology

research was published in 2006 (CRDC 2006). There has always been interest in soil borne disease management, but interest has grown in soil biology interactions with the traditional areas of soil structure and crop nutrition. At a cotton industry workshop in 2001 on soils research and development, soil biology was considered the top priority (Roth 2001).

An overview of soil biology in cotton production systems can be found in Seymour *et al* (2006) and for the grains industry where cotton is grown by Bell *et al* (2006). They concluded that biological activity in cropped soils is impacted negatively by tillage, irrigation, pesticides, fertilizer application and that the biological biomass is less than in uncropped soils. They also conclude that stubble retention and adoption of zero tillage produced small but positive impacts on the level of biological activity. Other options to improve soil biology are also being evaluated by cotton growers such as use of livestock manures, biological additives, and gin trash.

Questions have been asked in relation to genetically modified cotton and soil biology. Field experiments on the rhizosphere microbial population size, diversity and function do not appear to be influenced by the presence or absence of genetically modified traits currently available in cotton. However, in the glasshouse, significant differences in composition of rhizosphere bacteria

Figure 26 Variation of soil organic carbon in the 0–0.6m. depth with time in irrigated and dryland cotton farms in NSW and Queensland



were observed between cotton varieties, not the presence or absence of the *Bt* gene (Knox 2006).

There are no simple ways for growers or the industry to monitor and report soil biology trends. This is a complex matter and has been the focus of much discussion as summarised at the cotton industry farming systems reviews.

Crop diseases

Crop diseases are one of the greatest threats to cotton industry sustainability. The cotton industry undertakes an annual disease survey in both NSW and Queensland. The current trends are an increasing distribution and incidence of Fusarium wilt (*Fusarium oxysporum*) and black root rot (*Thielaviopsis basicola*) (Allen et

al 2008). Fusarium wilt has now been confirmed on 82 farms in NSW (Allen et al 2008) (Figure 27). The Darling Downs in Qld has been the region most affected by Fusarium wilt.

Verticillium wilt (*Verticillium dahlia*) has been a disease the cotton industry has been constantly managing. In the 1980s verticillium levels were rising, which lead to the development of resistant varieties and a corresponding fall in the disease incidence. Figure 28 shows the rising verticillium wilt trends in the 1980s, which declined again in the 1990s following the release of more resistant varieties (Allen et al 2008). There has been a sharp rise again in verticillium wilt levels during the most recent cotton season 2007–08 due to cool conditions, which will need to be monitored by the local growers.

Figure 27 Fusarium wilt on cotton farms

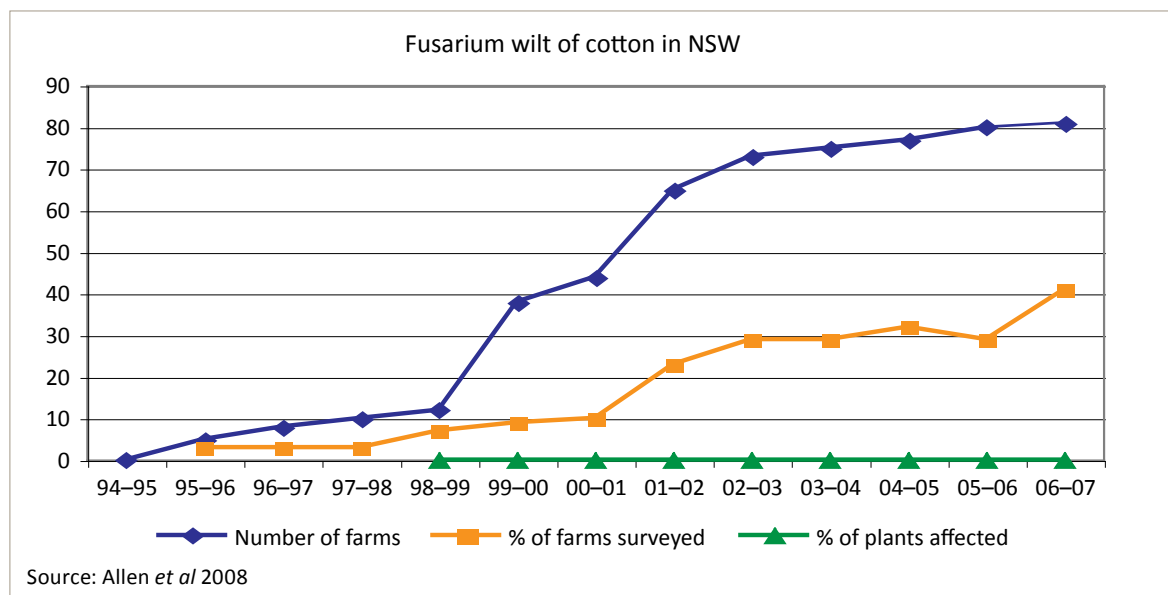
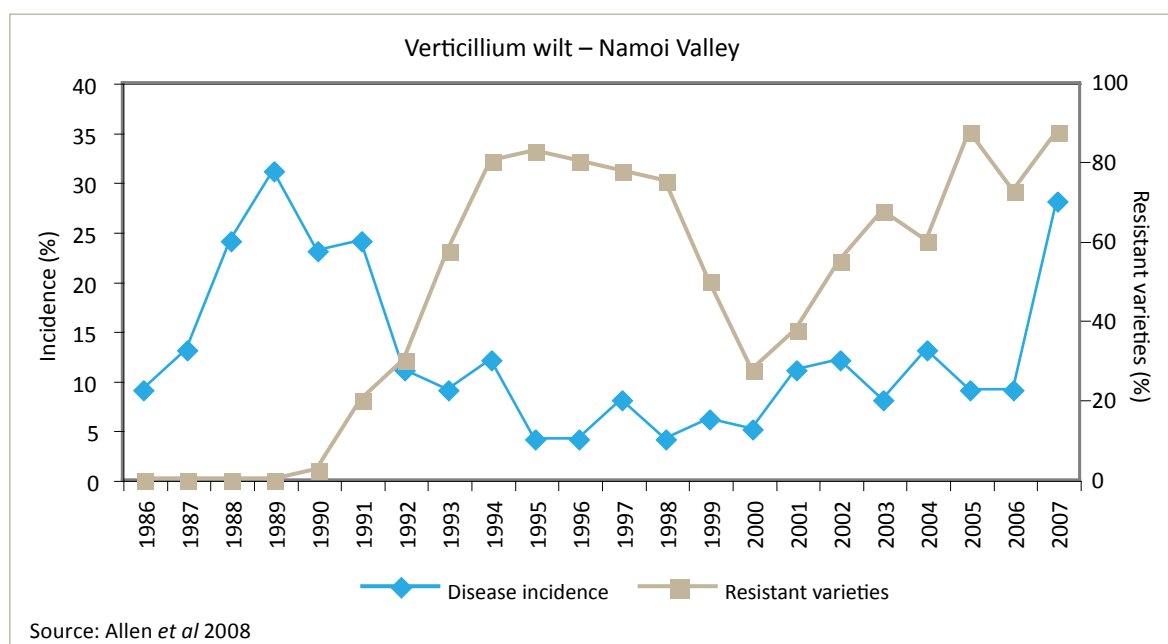


Figure 28 Verticillium wilt on Namoi Valley cotton farms 1986–2008



Since the discovery of Black root Rot (*Thielaviopsis basicola*) in 1989 researchers have monitored 30 farms in north west NSW. As a result of the exponential spread of the disease in the 1990s they found by 2003 that 97% of the farms, 72% of the fields and within fields 36% of the plants in NSW in 2003 were infected with Black Root Rot (Figure 29) (Nehl *et al* 2004). Fortunately for cotton growers, the incidence is not directly related with cotton seedling mortality and seedling mortality hovers around 40%, although there has been a significant increase in the southern cotton regions in recent years (Chris Anderson, NSW DPI, pers. comm. October 2008).

Crop diseases remain a constant threat to the sustainability of the cotton industry. The emergence of new diseases such as Tobacco Streak virus, Anthracnose, cotton leaf curl virus, and Texas root rot, remain a potential biosecurity and sustainability risk. Management options for the major cotton diseases have been outlined in Allen *et al* 2008.

Soil erosion

Soil erosion has been a significant long term problem for Australian agricultural industries. Estimated soil losses in irrigated cotton fields caused by furrow irrigation have been reported of 4–8 t/ha per year (Silburn *et al* 1998) and 5.25 t/ha (McHugh *et al* 2008). Many growers have tried the use of polyacrylamide or “PAM” products to increase water infiltration. It has been estimated that one in five fields may be treated with polyacrylamide products (Misra and Hood 2007). The use of stubble and other techniques for stabilising soil erosion on cotton farms have been summarised in Silburn *et al* (1998). Drip and lateral move irrigation systems also reduce the amount of soil erosion. The offsite impacts of eroded sediment and associated attached nutrients and pesticides are a major environmental risk of the cotton industry.

The monitoring of erosion is carried out by 44% of growers in 2006 (CCA 2007a) and 40% in 2007 (WRI 2007a). Table 20 shows the cotton BMP rankings trend for soil erosion management is improving. It would be useful for the cotton industry to quantify soil erosion rates under the more modern farming systems which include stubble incorporation, use of storm water management plans, precision farming and new irrigation methods such as centre pivots and reduced furrow lengths.

Figure 29 Black root rot incidence on plants, fields and farms

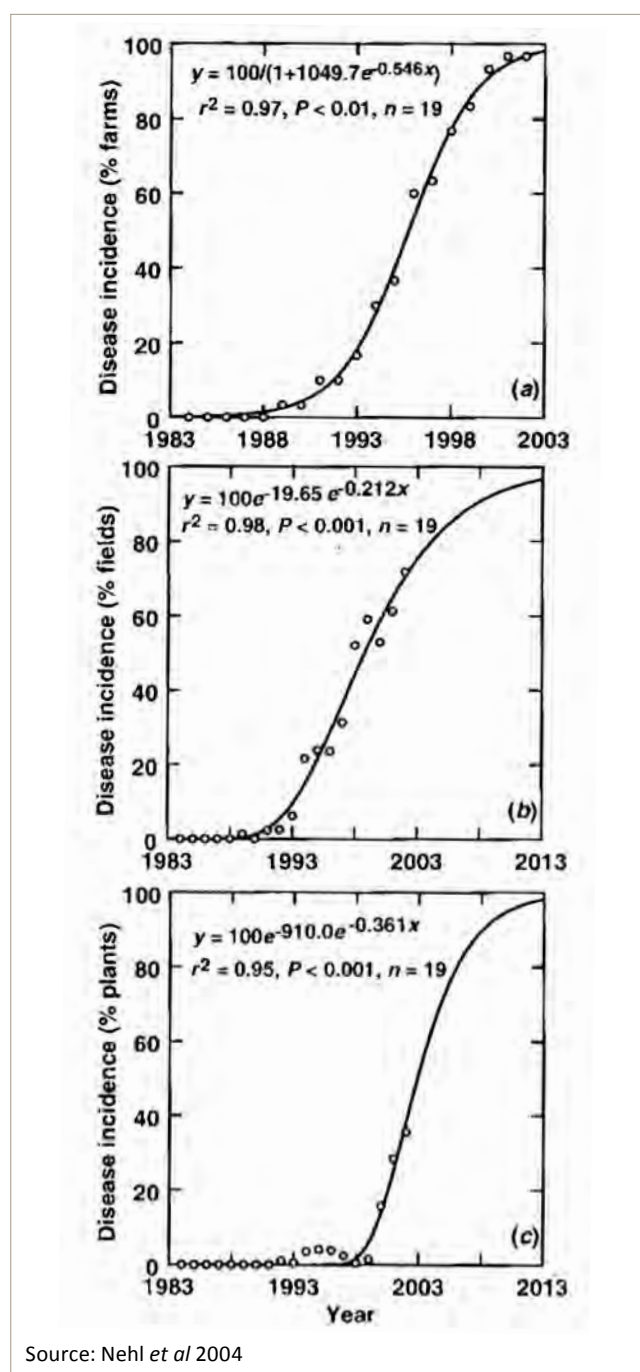


Table 20 Mean BMP land and water module rankings relevant to soil health 2006–2008

MANAGEMENT COMPONENT / BMP RANKING AND YEAR	2006	2007	2008	TREND
Soil management – structure and operations	1.7	1.3	1.4	Improving
Soil management - nutrition	1.5	1.1	1.2	Improving
Soil management – salinity and sodicity	2.1	1.6	1.7	Improving
Soil management – erosion	1.9	1.6	1.6	Improving
Scale of index is 1–4 (good to bad)				

Soil pH or acidity

Soil acidification is considered a major soil sustainability issue for Australian agriculture, especially in the sheep wheat belt where improved pastures and fertiliser use are causing a fall in soil pH. In cotton regions, soil acidification is not of concern as the vertosol soils where cotton is mostly grown are alkaline. The typical pH of soils where cotton is grown is greater than 7.5. Soil tests will enable long term trends to be monitored as shown in the case study at the end of this chapter.

Soil Cotton BMP rankings

Chapter 6 found the BMP system can provide a quantitative way of monitoring soil management trends at the farm and industry level. There is great potential to enhance this management system as an industry wide monitoring tool. On average, BMP rankings are around 1.5 on a scale of 1 – 4 for soil management (Table 20). This means growers are visually monitoring soils for structure problems and field operations are usually not carried out when the soil is wet. The ranking for nutrition indicates that nutrient applications are based on soil tests every one to two years as well as field observations. For salinity and sodicity, water and soil tests are taken, but these are not done in a regular cycle. For erosion, action is taken to monitor erosion and action taken to fix it where possible. These findings are consistent with other data presented in this chapter.

Precision agriculture

Precision agriculture and associated technologies such as remote sensing, geographic information systems, yield mapping, variable rate applications, soil sensors such as electromagnetic induction, ground penetrating radar have all been used in the cotton industry.

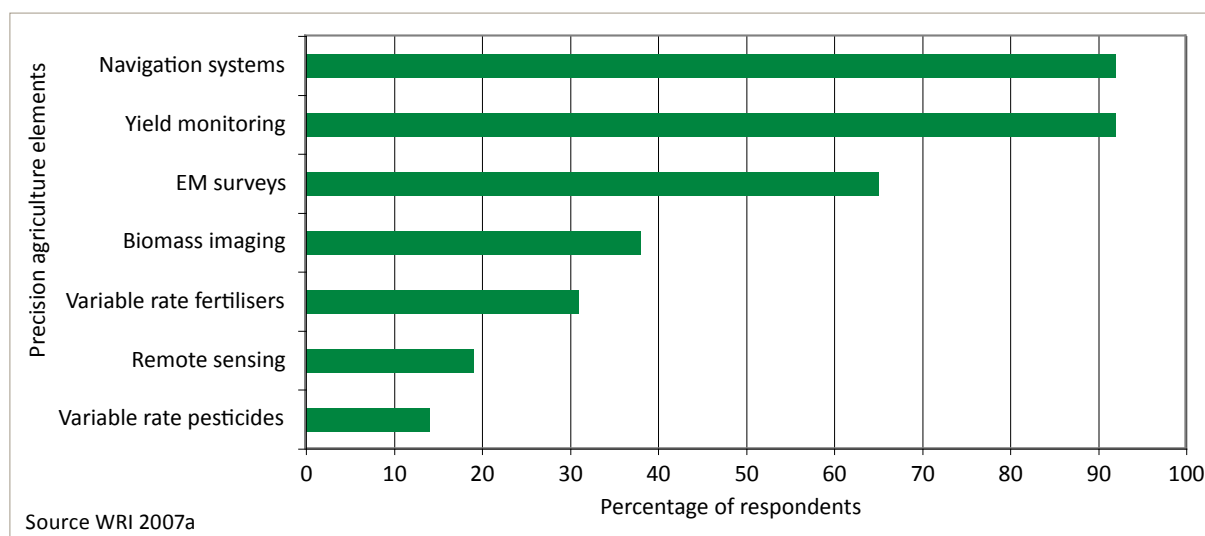
A grower survey in 2006–07 found 54% of respondents were using precision agriculture methods. Of these the most commonly collected information was that relating to navigation systems and yield monitoring, followed by electromagnetic (EM) surveys (Figure 30).

Soil research priorities

A study in 2005 on soil research priorities of growers found the five main areas of concern were measurement of VAM (Vesicular Arbuscular Mycorrhizae), measurement of other soil biota, soil structure, nutrition and organic carbon content (Shaw 2005). Other important issues raised in the report included the need to extend information on residual herbicides, greenhouse gases, managing sodic sub-soils, and nutrient recycling. By comparison, the 1996–97 cotton benchmark survey found pupae control, soil compaction, and cotton stubble management were the most important research issues (CRDC 2000a).

Although there will always be more to learn, the cotton industry has realised the importance of the physical and chemical aspects of its soils health, but now needs to direct greater effort into the more unknown field of soil biology. Major constraints of biological activity in irrigated cotton soils identified already include the lack of carbon and the presence of agrochemicals. High levels of spatial and temporal heterogeneity, soil type effects, sampling problems and interpretation difficulties are some of the challenges with benchmarking the biological components of the soil. There is a need for more research in the biological area of soil management and greater cross linkages between the chemical, physical and biological disciplines as well as the grain industry. If the biological component could be quantified for benchmarking it could then be incorporated with the chemical and physical attributes for growers to have an overall soil health score for their farming system. It is unlikely this will be a practical option for many years as it requires further research.

Figure 30 Precision agriculture on cotton farms 2006–07



Long Term Soil Health: a 27-year example

Monitoring the soil nutrient status is highly recommended to manage soil fertility and avoid nutritional stress of cotton crops. Soil testing is an important tool for fertiliser management decisions each year. Usually, soil tests are taken, results are examined and the fertiliser decision is made. At this point, most soil test results sheets are filed away in a bottom drawer and forgotten about in much the same way as old income tax files. However, monitoring changes in soil fertility over time is just as valuable as using soil test results to indicate fertiliser requirements. Long term monitoring provides reassurance that cropping systems are sustainable and soil health indicators are heading in the right direction.

There are some cotton research experiments that report 10 to 15 years of soil data trends but soil data sets spanning 20 years or more in irrigated cotton are very rare in Australia. The aim of this case study is to encourage growers to keep their soil test data over a long period of time, so they can demonstrate their farming practices are sustainable with some quantitative data.

Since the early 1980s Geoff Hewitt has been monitoring his cotton and grain crop nutrition with soil tests on the Darling Downs, near Macalister, in Queensland. His aim is to maintain and improve the soil fertility of his farms, whilst increasing cotton and grain yields.

Soil tests are used as one of the many tools to assist in fertiliser decisions. Not every field is tested each season but there is a program in place to test two to three fields per year. Over time, a detailed picture of soil health trends is built up across the farm. Soils are sampled at 30 cm. Geoff says, "It is reassuring to know we are doing the right thing or when things don't work out, we can see the correction take place in time".

Murray Boshammer, Senior Agronomist at Total Ag Services in Dalby, has been working with the Hewitts on their crop agronomy and has compiled 27 years of soil testing data for each field into a series of spreadsheets for long term monitoring. Soil testing is done after harvest of each crop. Over the years soil testing laboratories have changed and when this happens split samples are sent to both the old and new



laboratory so that comparisons can be made with historical data. Soil samples have also been taken in nearby grassland, under a 60 year old fence line. The grassland has never been fertilised, cropped nor grazed heavily and provides a useful comparison of soil in its natural condition.

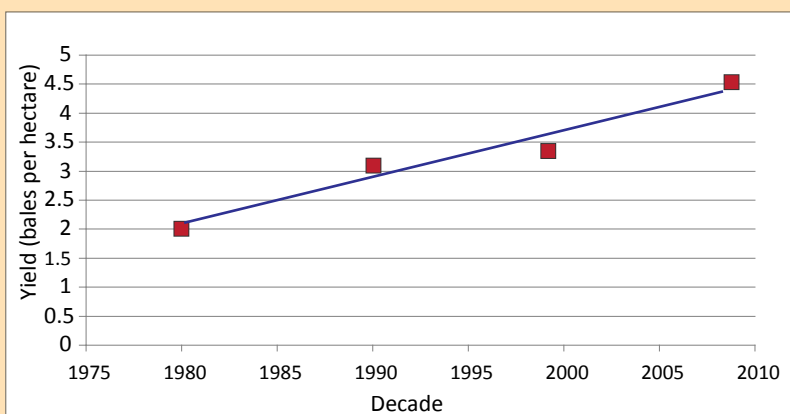
The solution

Backhoe pits are used to monitor soil structure, which on this property is in excellent shape. Crop rotations, cow manure, controlled traffic and minimum tillage have been key strategies to improve soil structure. When it comes to tractor time, it is a case of less is best, and no longer are 4WD tractors ploughing hectares of land.

In terms of nitrogen application, anhydrous ammonia has not been used for nine years. Improvements in technology over the years mean nitrogen application techniques have become much more uniform, which has been very beneficial for the cotton. Currently, fertilisers are applied in split applications consisting of a combination of up-front fertilisers and side dressing. About 160 kilograms of nitrogen per hectare as urea, 80 kilograms per hectare of Starter Z for phosphorus and zinc and 30 to 40 kilograms per hectare of potassium sulphate are commonly used. Phosphorus, potassium, sulphur and zinc are applied using variable rate technology, which is beneficial in fields with variable soil types.

Feedlot manures have been used for about 15 years at a rate around 10 tonnes per hectare when it can be obtained. The manure has helped to reduce fertiliser needs but one of its main problems is the variable amount of nitrogen it contains. This ranges from 1.6 to 3.2 per cent, which makes it

Figure 31 Cotton yield per hectare since soil testing began on Armour, 1980–2007



challenging to fine-tune crop needs. On some fields poor quality bore water was used, but this practice has ceased as the soil data was showing that it was not a sustainable practice.

The future

In the last 12 months fertiliser prices have tripled and it is now very difficult to secure enough fertiliser when it is needed. The future will include fine tuning site sampling and targeted variable rate applications of nutrient inputs with the use of global positioning systems technologies. According to Geoff and Murray the key is adaptive management and using a variety of the options that are available. According to Geoff Hewitt: "A flat line is a good result when it comes to looking at the long term soil trend data. The data can be erratic but, over time, when combined with our experience, good sense can be made of most numbers"

Crop yield

Figure 31 shows that yields have increased significantly since cotton was first grown on the farm.

Soil pH

Figure 32 shows the soil pH is alkaline and has fluctuated between 7.5 – 8.5 which means its slightly to moderately alkaline. These are pH levels common to soils where cotton is grown. The variability is likely to be measurement and site variation.

Soil organic carbon

Between 1981 and 2008 a range of crops have been grown, mostly cotton and fallow rotation up to year 2000, with other crops including millet and sorghum in the mix after 2000. Figure 33 shows how oraganic carbon levels are low and have been approximately 1% since 1981. The dip around 2003 was caused by the bare fallow that season. Sorghum was grown in 2007 which may explain the increase in soil carbon %. Cotton was last grown in 2004, and the rise in 2007 is a result of two sorghum crops. The key message is that organic carbon levels have remained low and will vary depending what crops are grown.

Soil phosphorus

Figure 34 shows the available phosphorus levels (Colwell test) have fluctuated with the addition of fertiliser and crop removal of cotton lint or grain. Generally, P fertiliser should be applied when the Colwell P is less than 10 – 15 ppm. High amounts of MAP fertiliser have been used by the grower who thinks he has been putting on excess, which is causing the large fluctuations and high values.

Soil potassium

Soil potassium levels have also varied over time (Figure 35). Potassium is now applied every year to maintain soil potassium levels. There is some conjecture on the critical levels of soil potassium and levels around 0.6

Figure 32 Soil surface (0–30 cm) pH (water) levels between 1981 and 2007

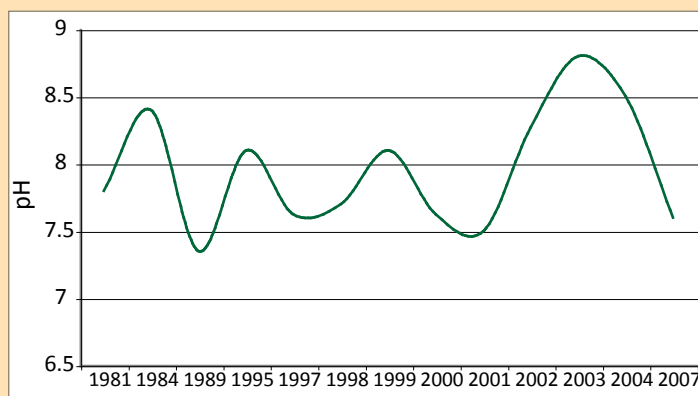


Figure 33 Soil carbon levels between 1981 and 2007 levels between 1981 and 2007

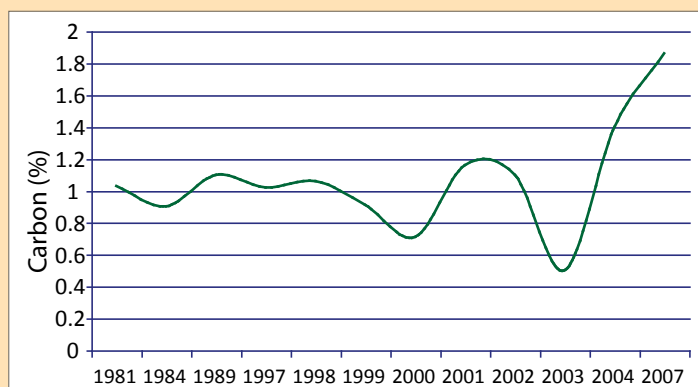


Figure 34 Soil-available phosphorus levels (Colwell test) between 1981 and 2007

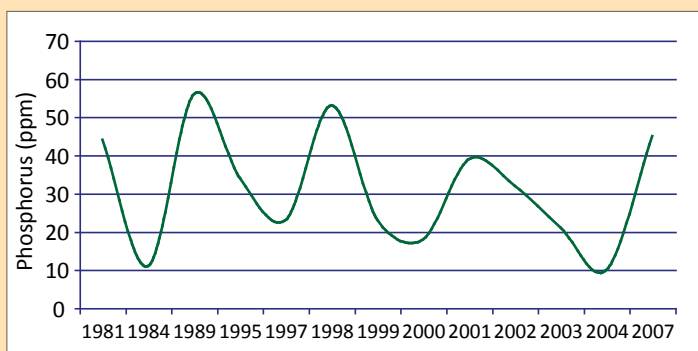
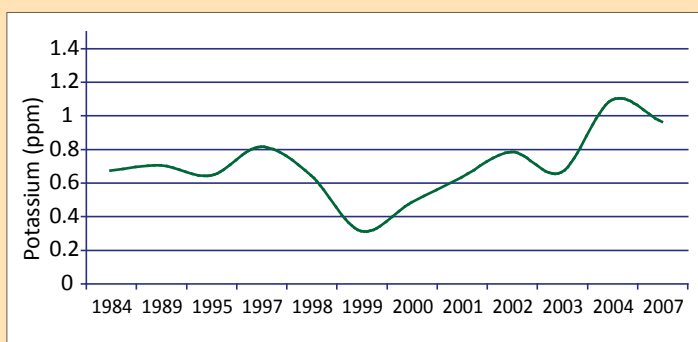


Figure 35 Soil potassium levels between 1981 and 2007



meq / 100g are used on this farm. The dip in 1999 may have been caused by a high yielding chickpea crop (1998) followed by cotton in 1999 without the addition of potassium fertiliser.

Soil electrical conductivity

The electrical conductivity (EC) levels are very low (Figure 36). The gradual increase was being caused by the use of poor quality irrigation water. The spike in 2001 was caused by the use of poor quality irrigation water, a practice which has since ceased. As discussed earlier in this chapter critical levels are 1.5 dS/m for seedlings and 7.5 dS/m for more mature plants. These measurements have been taken in the 0–30cm zone and it is also important to monitor EC levels deeper in the profile around 70 cm.

Soil chloride

The soil chloride levels are low except for the large spike due to poor quality water in 2001 (Figure 37). Chloride levels up to 300 ppm are considered satisfactory. These measurements have been taken in the 0–30cm zone and again it is more important to look at chloride levels deeper in the soil profile. The presence of a high concentration of chloride is a key predictor of chemical sub soil constraints.

Soil sodicity

Sodicity is best monitored with the Exchangeable Sodium Percentage (ESP%). The critical level is and ESP% greater than 5. The ESP% in Figure 38 is high which is common in cotton region soils. The ESP% values are also trending upwards.

Soil calcium and magnesium

Most soil tests will include other cations such calcium and magnesium. Soils where cotton is grown generally have very high levels of calcium and magnesium. Critical levels for calcium and magnesium are around 5 meq/100g. Figure 39 shows the calcium and magnesium levels are well above the critical measures. There are other important issues related to their balance and a discussion of those can be found in the cotton nutrition literature.

“A flat line is a good result when it comes to looking at long term data. The data can be erratic but over time, when combined with our experience, good sense can be made of most numbers.”

Geoff Hewitt

Acknowledgements:

Geoff Hewitt

Murray Boshammer, Senior Agronomist with Total Ag Services of Dalby

Figure 36 Soil electrical conductivity levels between 1981 and 2007

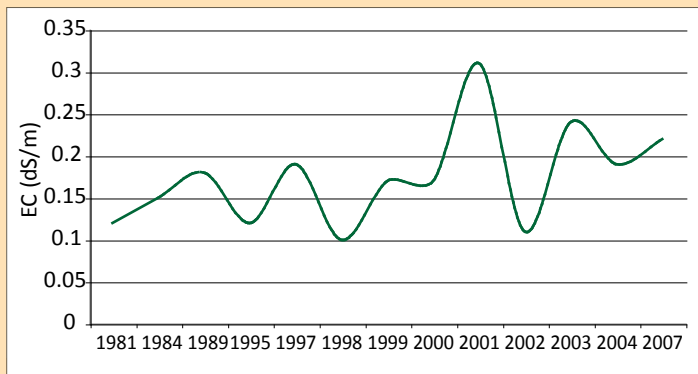


Figure 37 Chloride levels between 1981 and 2007

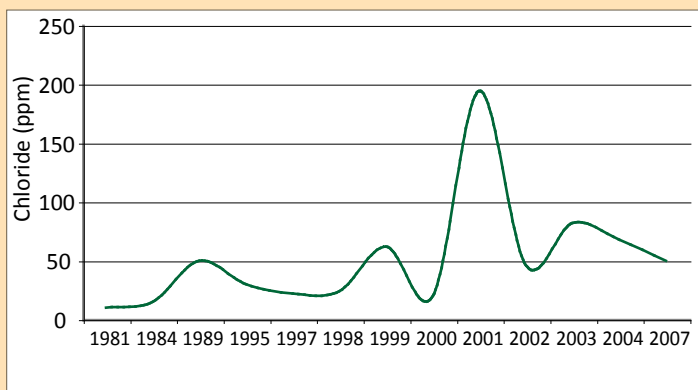


Figure 38 Exchangeable sodium % levels between 1981 and 2007

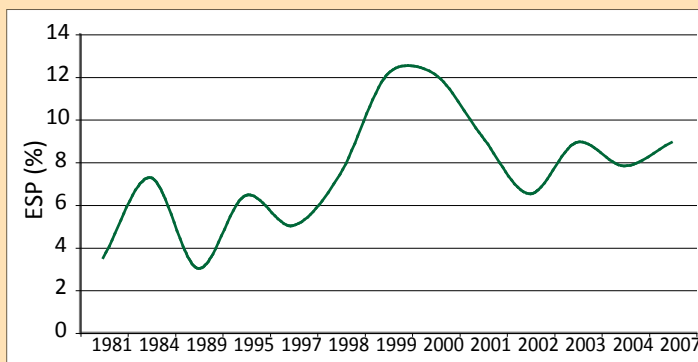
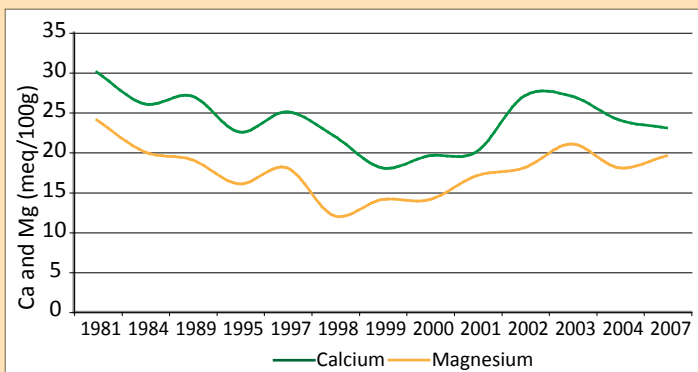


Figure 39 Calcium and magnesium levels between 1981 and 2007



WATER

Introduction

Water is critical to agriculture and is the major limiting factor for the Australian cotton industry. Figure 2 showed the dips in production as a result of water shortages. In most years, 80–90% of Australian cotton crop is irrigated. Irrigation allows cotton growers control over the water supply to a crop to increase yield and optimise fibre quality. Due to the high variability of rainfall where cotton is grown, dams have been constructed to store water during dry times to facilitate annual crop production. These dams are both on farms as well as the major river storages. Water for irrigation is accessed from rivers, floodplain water harvesting and groundwater sources. For example, in 2003–04 the proportion of water accessed from the river was 66% and groundwater was 30% (ABS 2006). These figures do not include floodplain harvesting, which can be significant. It is likely the proportion of groundwater would normally be less as during drought years such as 2003–04, groundwater use is higher.

Market research with cotton growers found the key issues affecting their water management were the availability, continued security and cost of water, economic returns per megalitre, water quality and water scheduling (Callen *et al* 2004). Other important issues that have arisen since that research include rising energy costs for pumping, labour shortages for irrigating, and the National Water Initiative and its associated reforms of government policy.

A number of reviews have been conducted on the impact of irrigation on river flows on river health and aquatic biodiversity (Lake 1995; Thoms and Cullen 1998; Bunn and Arthington 2002; Kingsford and Auld 2005). These reviews also highlight the importance of wetlands for the hydrological cycle, nutrient cycles and biodiversity. A study has recently been completed on the impact of irrigation pumps on native fish (Baumgartner *et al* 2007) and a project is now underway to help mitigate any potential impacts.

Water use data has considerable variability caused by rainfall, runoff and challenges with measurement. Thus, caution should be exercised when examining water figures for any single cotton season.

Water use

Agriculture is the major water user in Australia. In 2004–05, agriculture accounted for 65% of the water used in Australia, while in the Murray Darling Basin agriculture accounted for 83% of the water diverted (ABS 2007). In 2003–04, 2.4 million hectares of agricultural land and 10,000 gigalitres of water were used for irrigated agricultural activities in Australia (ABS 2006). There are about 40,000 irrigators using 0.5 percent of all agricultural land in Australia. The gross value of irrigated production is about \$9 – 1.5 billion. Prior to the drought, half the profit from Australian agriculture was generated from irrigated production systems (NLWRA 2002).

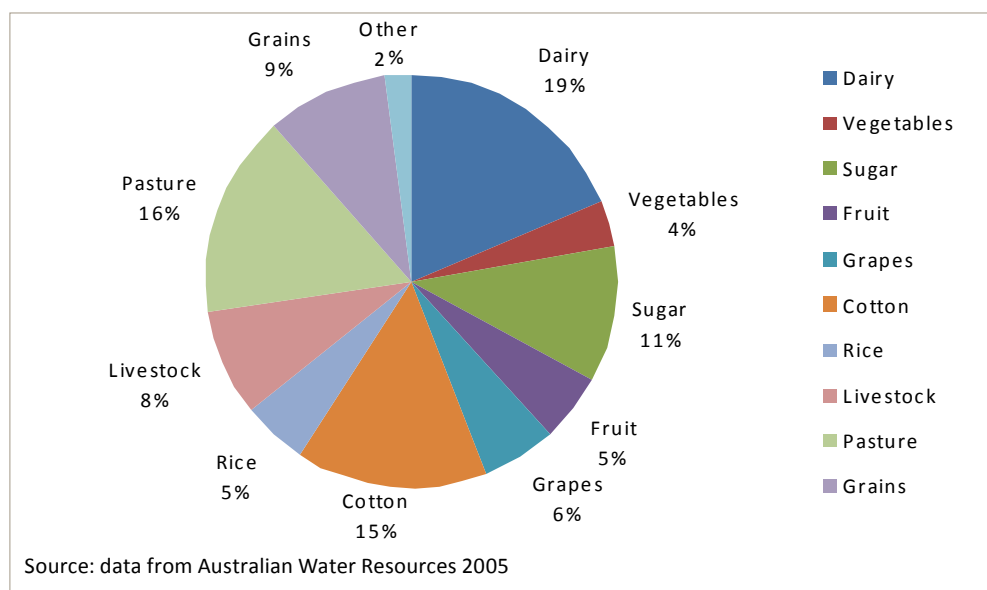
Table 21 shows water consumption for the major agricultural industries in 2000–01 and 2004–05. During this period water

Table 21 Agricultural water consumption in Australia 2000–01 and 2004–05

INDUSTRY	2000–01 (GL)	2004–05 (GL)
Dairy	2593	2276
Vegetables	507	455
Sugar	1235	1296
Fruit	645	648
Grapes	656	717
Cotton	2896	1822
Rice	2223	631
Livestock	n/a	1035
Pasture	n/a	1928
Grains	n/a	1162
Other	n/a	249
Total	14989	12191

Source: Australian Water Resources 2005

Figure 40 Water use by major crops in Australia for 2004–05



consumption by agriculture was reduced by 23% due to the drought. Cotton water use was reduced by 37%, while rice was dramatically less (72%). In 2004–05, cotton used 15% of the water used by agriculture in Australia. The livestock industries used 43% (dairying – 19%, pastures –16%, and livestock – 8%) (Figure 40, on the previous page). Sugar used 11%, grain crops used 9%, and horticulture crops (vegetables, fruit) used 9% of the water. In 2004–05, rice water use was only 5%; in the past this has been normally higher, around 10%.

Irrigation water use levels and compliance

Water use for irrigation is governed by various statutes and regulations of Government. There are prescribed volumes of water that irrigators are allowed to use according to water sharing plans regulated by Government. Table 22 shows the volumes of water and sources of water use in the Darling Basin where most cotton is grown (with the exception of Emerald). More detailed figures on each river valley can be found in the Australian Water Resources 2005 report (AWR 2005).

The CSIRO has recently completed a major report for the Australian Government on water availability in the Murray Darling Basin (CSIRO 2008). The key findings include that the total flow of water at the Murray River mouth has been reduced

by 61% and the river ceases to flow 40% of the time, compared to 1% of the time in the absence of water resource development. The report examined the potential impact of climate change and although there is some uncertainty in the south of the Darling Basin a decline in water availability is possible, while in the north increases are possible. In the Darling catchment, current global climate change models disagree on future rainfall predictions, with slightly over half the models indicating rainfall will be less in the future. The annual average surface flow is predicted to fall between 2–4% in some of the river systems where cotton is grown.

There is considerable debate in the community around sustainable water use figures. Once an agreed target is reached it is important for the cotton industry to report its compliance as part of a sustainability report. For sustainability reporting, an indicator of the proportion of water used that conforms to the legal limits of water sharing plans or the number of breaches of licence permits would be valid. This data is not publically available, but the figures are very low and close to zero indicating high compliance.

Irrigation water extraction figures for each river valley are kept by the State agencies and the Murray Darling Basin Commission,

Table 22 Average surface water use in selected valleys of the Darling Basin (water use volumes in Gigalitres per annum)

VALLEY	TOWN AND STOCK AND DOMESTIC EXTRACTION	OTHER RIVER SYSTEM EXTRACTIONS				TOTAL RIVER SYSTEM EXTRACTION	% OF TOTAL RIVER SYSTEM EXTRACTIONS	EXTRACTION FROM HILLSIDE DAMS	TOTAL SURFACE WATER USE	% OF TOTAL SURFACE WATER USE IN THE BASIN
		Extraction from rivers	Floodplain harvesting	Rainfall harvesting	Total other					
Border Rivers	5	400	13 <i>d</i>	<i>a</i>	413	418	14%	24 <i>c</i>	442	14%
Moonie	0.2	30	4 <i>d</i>	0 <i>e</i>	34	34	1%	25 <i>c</i>	59	2%
Gwydir	14	318	82 <i>d</i>	15 <i>e</i>	415	429	15%	17 <i>c</i>	446	14%
Namoi/Peel	13	346	14 <i>d</i>	74 <i>e</i>	434	447	15%	80 <i>c</i>	527	16%
Macquarie	45	412	<i>a</i>	<i>a</i>	412	457	16%	53 <i>c</i>	510	16%
Condamine Balonne	16	533	144 <i>d</i>	<i>a</i>	677	693	24%	67 <i>c</i>	760	24%
Nebine	0.2	5	0.8 <i>d</i>	0 <i>e</i>	5.8	6	0%	<i>b</i>	6	0%
Warrego	0.1	49	0 <i>d</i>	0 <i>e</i>	49	49	2%	4 <i>c</i>	53	2%
Paroo	0.2	0	0 <i>d</i>	0 <i>e</i>	0	0.2	0%	<i>b</i>	0.2	0%
Barwon Darling	18	198	13 <i>d</i>	29 <i>e</i>	240	258	9%	<i>b</i>	258	8%
Total Darling above Menindee	112	2291	271 <i>d</i>	118 <i>e</i>	2680	2792	95%	270 <i>c</i>	3062	
Lower Darling	11	122	<i>a</i>	<i>a</i>	122	133	5%	<i>b</i>	133	4%
Total Darling Basin	123	2413	271 <i>d</i>	118 <i>e</i>	2802	2925		270 <i>c</i>	3195	
% of total water use	4%	76%	8% <i>d</i>	4% <i>e</i>	88%	92%		8% <i>c</i>		

Notes

a Not calculated by computer models for these valleys.

b No data but probably very small.

c The accuracy of estimates of water use from hillside dams is likely to be poor.

d The accuracy of estimates of floodplain harvesting may be poor.

e The accuracy of estimates of rainfall harvesting may be poor.

Source: Webb, McKeown & Associates 2007

National Water Commission and in the future The Bureau of Metrology. The quality and availability of this data is improving rapidly as a result of the National Water Initiative.

Water trading

Between 2000–01 and 2003–04, 54% of cotton farms participated in some form of water trading with 10% of cotton farms trading water every year (ABS 2006). These figures are similar to other broad acre crops and pastures. Interest in water trading figures is likely to increase in the future with increased implementation of the National Water Initiative.

Cotton crop water use

A comprehensive discussion on the physiology of cotton plant water relations can be found in Hearn and Constable (1984) and Hearn (1994). The latest management practices of water application continue to evolve and were recently compiled in the WATERpak manual for irrigated cotton and grains (Dugdale *et al* 2008). There is also a large amount of research underway and a summary of current cotton water research projects can be found in Roth (2007). The opportunities for improved water use efficiency have been compiled in the Northern Murray Darling Basin for a range of crops by Baillie *et al* (2007).

An important part of improving water use efficiency is knowing how to measure it. This is easier said than done, and caution should always be exercised when examining water use figures to ensure they include the same parameters. Most cotton growers measure their water use and calculate water use efficiency. In surveys when growers were asked if they measure water use efficiency, 60% said they did in 2005–06 (CCA 2007a) and 76% measured it the following year 2006–07 (WRI 2007a). In these surveys growers stated they found water use efficiency measurement a difficult task.

Generally, farmers will refer to the amount of cotton grown per megalitre of irrigation water used in terms of bales per megalitre. When comparing crop water use figures from growers, it is critical to check whether the numbers include or exclude rainfall. Summer rainfall is an important source of water during the crop growing season. A further difficulty with water figures

is accounting for all the other variables either related to the crop yield such as pests, disease, salinity, hail, waterlogging, and extreme temperatures.

In order to achieve consistency of water use efficiency measurement, the cotton industry adopted standard measurements. These are listed below and further information can be found in the WATERpak manual:

- Crop Water Use Index (CWUI): lint produced per millimetre of evapotranspiration from a field during the cotton season,
- Gross Production Water Use Index (GPWUI): the lint produced per megalitre of total water used on a farm or field,
- Irrigation Water Use Index (IWUI): the lint produced per ML of net irrigation water applied to a field or supplied to a farm, and the
- Whole Farm Irrigation Efficiency (WFIE): the amount of irrigation water used by the crop for evapotranspiration as a percentage of that applied to the crop.

The WFIE provides the entire view of efficiency on a farm. The two components of this include the efficiency of the water supplied to the crop (IWUI and /GPWUI) and the efficiency with which the crop converts the water into cotton lint (CWUI). The GPWUI is the most important indicator for long term comparisons.

The water use efficiency of the Australian cotton industry has been assessed several times in the past 20 years and are summarised in Table 23.

There are several key points:

1. The amount of irrigation water applied ranges from 5.37 – 7.5 ML/ha. The amount of irrigation water used depends on rainfall and system efficiencies. Typically, 6 ML/ha of irrigation water is the figure commonly quoted in water use figures.
2. The seasonal evapotranspiration (ET) figures averaged 730 mm. Higher values would be expected in hotter regions (eg Bourke), while lower values in cooler regions such as the Darling Downs. Crops need to use (ET) between 700–800 mm of water for high yields.

Table 23 A summary of key water use figures in the cotton industry between 1988 and 2007

YEAR	IRRIGATION ML/HA	ET MM	YIELD BALES/HA	IWUI BALES/ML	GPWUI BALES/ML	CWUI KG/MM/HA	WFIE %
1988-95 ¹	5.37		6.73	1.48 (0.97 -1.96)	0.82 (0.62-0.94)	3.05	63 (49-78)
1996 - 99 ²	6.96	735	8.13	1.32 (0.65-1.71)	0.79 (0.47-0.93)	2.52	57 (20-85)
1998- 00 ³	7.5						(28-68)
2000- 03 ⁴	7.51	721	8.73	1.16	0.93	2.79	58
2006-07 ⁵		733	11.12	1.31	1.13 (0.82 – 1.71)		85
Average	6.8	730	8.68	1.32	0.91	2.79	66

Source: Data is from 1 Cameron Agriculture and Hearn (1997) 11 farms, 2 Tennakoon and Milroy (2003) 25 farms, Dalton *et al* 2001 7 farms, 4 RWUE (2003) 29 farms, 5 Williams and Montgomery (2008) 37 farms. Note that the range of some figures is shown in brackets

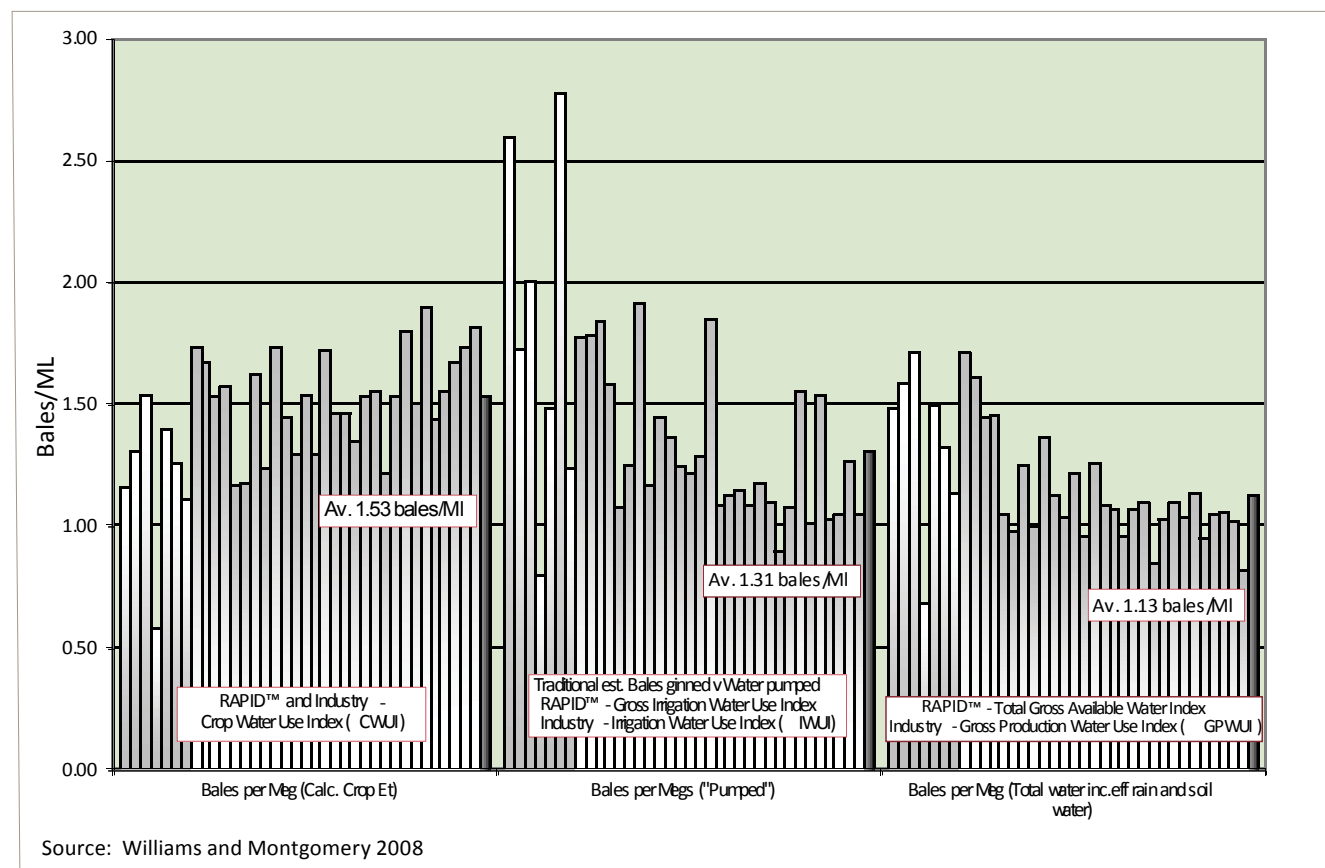
3. Cotton yields have been increasing with time.
4. A clear trend over time in the IWUI data is not expected as it depends if it is strongly influenced by rain. It averages 1.32 bales/ML. The major shortcoming of this index is that it excludes rainfall and stored soil moisture. These figures are higher when there has been more rainfall as less irrigation water is used and varies from year to year. This is the traditional figure that growers usually quote when asked.
5. The GPWUI includes irrigation, rainfall and water stored in the soil and is the best measure to make long term comparisons. The gross production water use index is improving. A comparison of the two studies 1998–95 and 1996–99 to the two studies 2000–03 to 2006–07 shows the GPWUI has increased 21% from 0.81 to 1.03 bales/ML.
6. The CWUI is rarely used by growers, but is commonly calculated in research trials. It is the efficiency the crop converted water supplied to it to cotton lint yield. It will provide more consistent comparisons from season to season. It has some limitations as it cannot account for differences in ET requirements between regions such a cool region (eg Breeza) compared to hot regions like Bourke. It is mostly dependent on agronomy inputs that affect yield rather than irrigation efficiencies. These figures were similar in all

the studies. Grismer (2002) has summarised figures from around the world and the Australian figures are amongst the world's best.

The WFIE figures show there is a wide range in the data, but on average are 66%. This means, on average 34% of the water is lost through inefficiencies in the irrigation system. There is considerable scope for improvement by growers at the lower end of the ranges, whilst the better growers have relative high efficiencies (around 85%). Some more data is needed post 2006–07 season before a definitive conclusion can be made concerning whether WFIE has improved over time.

Harris (2007) calculated a 25% improvement in the IWUI from 1.10 to 1.38 across the cotton industry between 2000–2006 (4.2% per annum) and claims greater improvements have been made by individual growers. A comparison between the studies of Tennakoon and Milroy (2003) in 1996–99 and Williams and Montgomery (2008) in 2006–07 shows the Gross Production Water Use Index increased on average from 0.79 bales/ ML to 1.13 bales/ML. This is an improvement around 40% in water use efficiency over the decade (4% per annum). In an earlier project, Queensland cotton growers improved their water use efficiency by 11% over 3 years,(3.7% per annum) (RWUE 2003). Thus, an

Figure 41 Water Use Index comparison



analysis of various reports shows that on average water use efficiency has been improving by 3–4% per annum.

Figure 41 shows the CWUI, IWUI and GPWUI for 37 farms in the 2006–07 season. The data show the range and variation around average figures with irrigation data in any one year.

An example of the variation in whole farm water irrigation efficiency was quantified by Dalton *et al* (2001). Figure 42 shows the best and worst case whole farm water balances for seven farms in the Border Rivers region between 1998–2000. On the best farm 65% was used for irrigation, which is consistent with the WFWI figures in Table 23. The major losses on the best farm were storage evaporation 14%, and in field deep drainage 11%. On the worst farm, only 21% was used with 39% lost in evaporation, 11% in storage seepage, 13% field deep drainage and 7% in the tail water.

Technology has made it possible to better measure water storage volumes and the drainage and evaporation losses. The Cotton Catchment Communities CRC and National Water Initiative are currently measuring 135 storages on cotton farms to assess their efficiency. By the completion of the project good figures should be available. Presently, less than 10% of growers have used storage meters (WRI 2007a).

Most cotton growers use surface irrigation and there is scope to improve its application efficiency. The major losses are in the form of tail water or deep drainage. It is now getting easier to undertake performance evaluations of surface irrigation systems. Smith *et al* (2005) examined 79 surface irrigation events and found efficiencies ranged from 17–100% with an average of

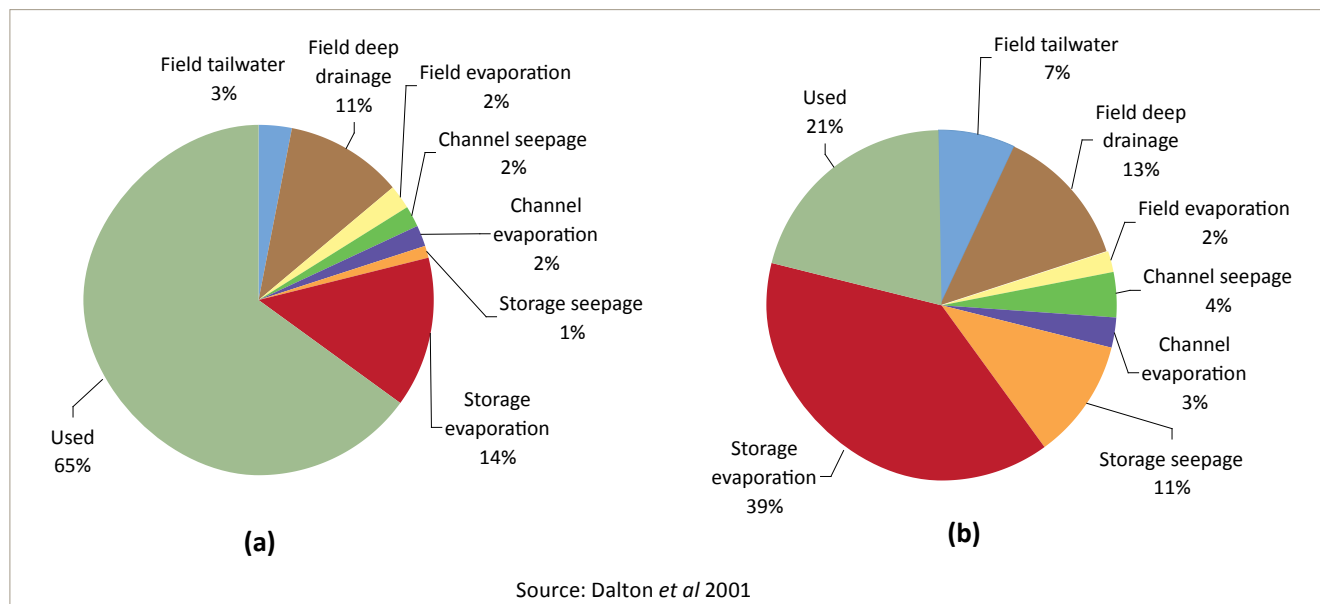
48%. They calculated irrigation losses of 1.6–2.5 ML/ha. Raine *et al* (2006) reported average savings of 0.15 ML/ha/irrigation when irrigators adjusted siphon flow rates and irrigation times.

In-field deep drainage has been the focus of much research in recent years and this has been summarised by Silburn and Montgomery (2004) who found typical figures were 100–200 mm/yr with a very large range 0–900mm/yr. For example, Dalton *et al* (2001) monitored 27 individual irrigation events over two seasons on seven farms and eleven fields. They found deep drainage was 75mm – 235 mm over the season. Results across five seasons in Queensland showed large deep drainage values are possible and vary with fields and season with a range between 0–3 ML/ha (0–300mm) (Gunawardena *et al* 2008). They also found deep drainage was dramatically less under a lateral move irrigation system, which is a common finding of growers who have adopted these systems.

Reviews have attempted to compare crop water use figures between countries around the world (Grismer 2002; Hearn 1994; Payero and Harris 2007). These reviews show that Australia is amongst the higher performing countries in the world, but is not always the best performer. International comparisons vary because of the different ways used to calculate the necessary figures, the amount rain received, different application systems or other underlying regional production problems such as extreme temperatures, disease, insect pests or soil problems like salinity.

The introduction of transgenic cotton varieties in Australia has led to discussion concerning its impact on water management. When comparing Bollgard® to conventional cotton, Bollgard®

Figure 42 Components of the volume balance for (a) best and (b) worst case measured whole farm efficiencies



was found to have a lower water requirement, but the conventional treatment was impacted by insect pest damage (Yeates *et al* 2008). Current results show considerable variation from year to year. Research on water stress or drought stress genes is underway and Monsanto have some early transgenic traits being evaluated in Australia. It is likely to be a decade before they are commercially available.

A survey of cotton consultants who managed most of the 2007–08 crop found 72% of 233 growers had implemented changes since 2003 to improve water use efficiency (WRI 2008). The types of improvements growers are making include objective irrigation scheduling, surface irrigation evaluations, storage efficiency calculations, installation of water meters, EM surveys and changing irrigation systems. A Namoi valley project between 2006–2008 improved their water use efficiency by 15% in two seasons (Spanswick and Jones 2008). This equated to at least 5000 megalitres of saved water over 8000ha of irrigated cropping land.

Irrigation methods

The majority of irrigation on cotton farms in Australia is by surface irrigation. In 2002–03, 93% of farmers were using surface irrigation, 6% overhead systems and no growers reported using drip irrigation (ABS 2006). Recently, there has been an increase in the number of cotton growers changing from surface irrigation to overhead systems (lateral move and centre pivots) or sub surface drip irrigation systems. WRI (2008) found 10% of respondents were using overhead systems.

A survey on drip irrigation in the cotton industry found that all growers who used sub surface drip irrigation reported decreased water use compared to surface irrigation, (Raine *et al* 2000). On average this was 2.56 ML/ha (38%) less than the surface irrigation. There is more potential for drip irrigation in particular on lighter textured soils. The high capital cost is the main constraint. As water costs rise there may be wider adoption.

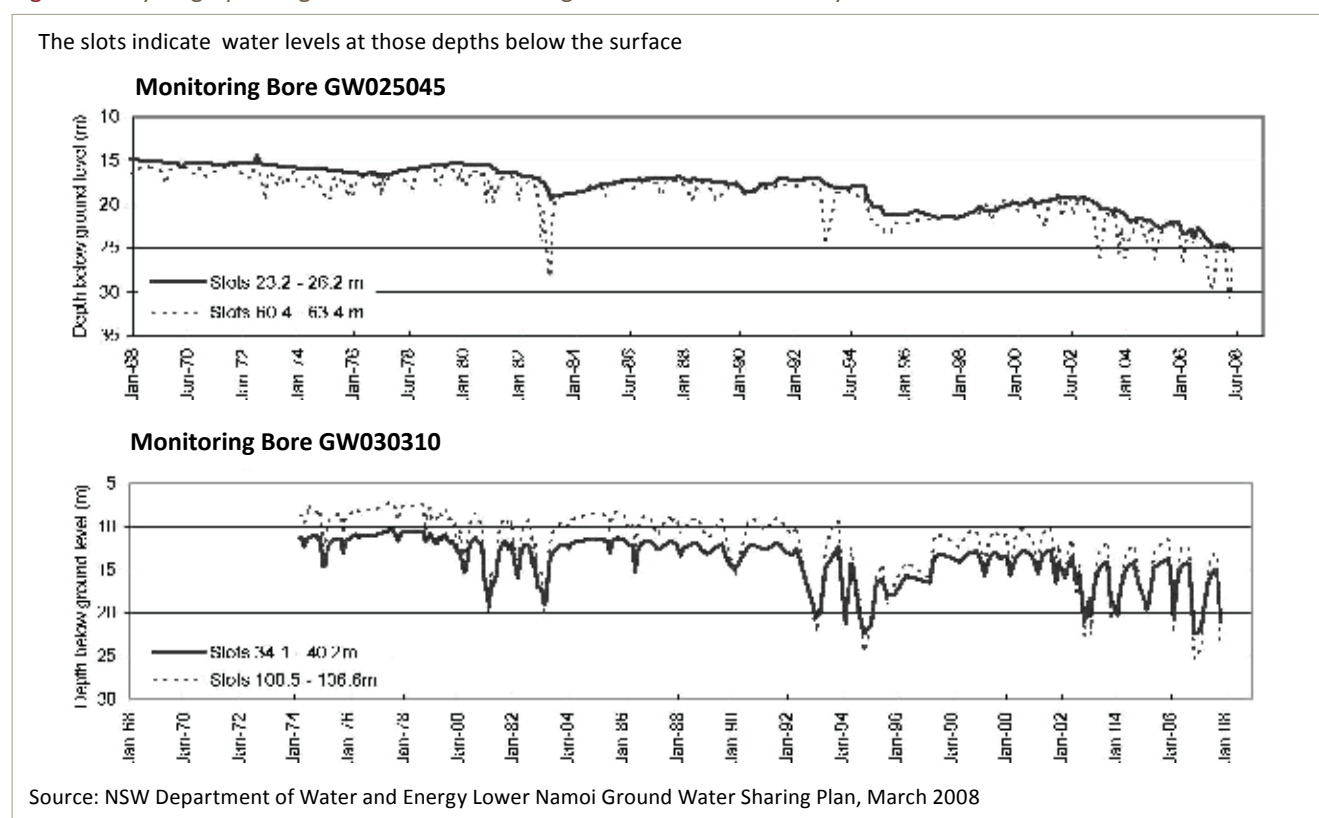
A similar survey was carried on growers using centre pivots and lateral move irrigation systems (Foley and Raine 2001). They found about 5300 ha of cotton was being grown under these irrigation systems, with 36 growers using 75 machines. All growers reported an improvement in the crop water use efficiency using these machines compared to surface irrigation. The average improvement was 0.8 bale/ML compared to surface irrigation. Grower applied 3.1 ML/ha less than fully irrigated surface systems, however the results indicated that average yields were slightly lower by 0.5 bales/ha.

It is expected that there will be a greater conversion of furrow irrigation to other systems such as centre pivots, lateral moves and to a lesser degree drip irrigation in the future. The major barriers to changing application methods include water allocation uncertainty and cost.

Groundwater levels

Groundwater levels are monitored by Government agencies. Groundwater sharing plans are available for each specific region and include groundwater levels and volumes of water pumped. An example of groundwater monitoring levels is shown in Figure 43. For this location, the long term decline in water levels is

Figure 43 Hydrographs of ground water monitoring bore in the Namoi valley



evident in these hydrographs as well as the seasonal variation. There are also differences between the measurement slot depths below the surface. However, all bores are different and these examples should not be extrapolated to other locations. The 2005–06 cotton grower benchmarking survey found that 53% of growers monitor groundwater levels (CCA 2007a). The University New South Wales will shortly be publishing some reports on groundwater levels for the Cotton CRC (Dr Bryce Kelly, UNSW, pers. comm., 20 March 2009).

Irrigation scheduling methods

Irrigation scheduling tools have been available for many years. The cotton industry is one of the most advanced agricultural industries in terms of its use of irrigation scheduling tools. The cotton industry has the highest use of soil moisture monitoring probes of any agricultural industry in Australia (around 40%) compared to irrigated pastures which is less than 5% (Montagu *et al* 2006; ABS 2006). Local knowledge of soils and past experience in the field are the other main methods used to schedule irrigations.

Water quality

Water quality is an important indicator of sustainability for agricultural systems. Consideration needs to be given to the water quality on-farm in water storages, groundwater bores as well as the surface water quality of the major river systems. The major water quality attributes are salinity, nutrients, and pesticides. There are many other water quality indicators and in June 2008 the Murray Darling Basin Commission released its Sustainable Rivers Audit 2004–2007 which includes a range of indicators such as fish condition and macro invertebrates status (MDBC 2008).

At the catchment scale, State Departments or Regional Natural Resource Management Bodies have undertaken some water quality monitoring. The volume and quality of the data varies between regions. At the commencement of this project in 2002

there was very little on-farm water quality data being collected. This situation has improved a little in recent years. This section provides a brief summary of water quality trends, using examples from specific regions. It does not attempt to collate all known data from all the different cotton regions.

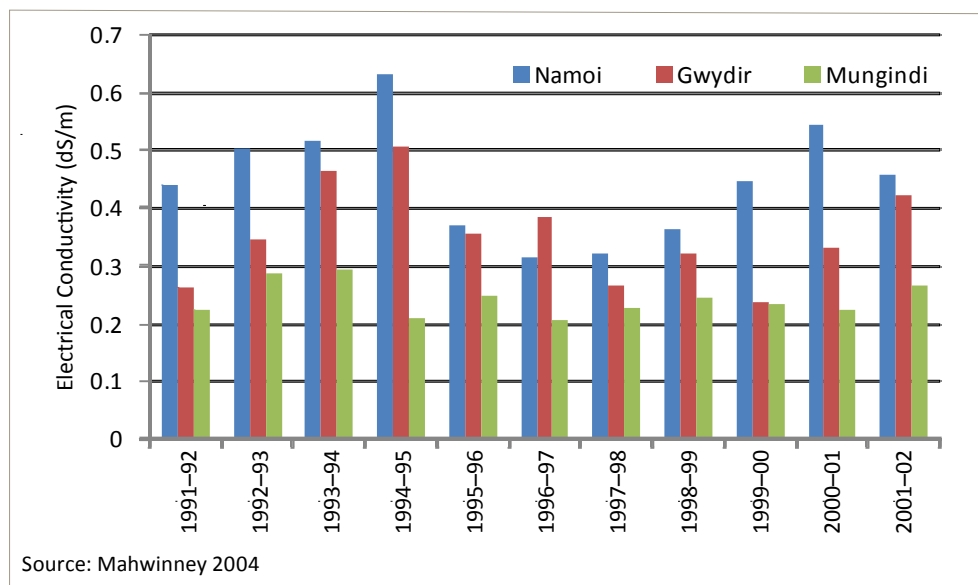
Salinity

Figure 44 shows the median electrical conductivity at three sites located at the lower end of the major cotton growing areas in the Namoi River (at Bugilbone), Mehi River (at Bronte) and Barwon River (at Mungindi). In most years the Namoi Valley had the highest electrical conductivity readings, while the Barwon River at Mungindi was consistently lower. The fluctuations from year to year are largely due to changes in flows due to rainfall, runoff and releases from storages (Mawhinney 2004). These EC values are all very low.

Insecticides

Endosulfan is an organochlorine insecticide, used to control sucking, chewing, and boring insects and mites in a range of crops, including cotton and sorghum. Figure 45, on the following page) illustrates that endosulfan concentrations, which were very high in 1991 have been below the Australian and New Zealand water quality guideline trigger value for 99% ecosystem protection (ANZECC and ARMCANZ, 2000b) for the last seven years (Mawhinney 2008). Table 24 shows the frequency of endosulfan detections has also fallen. The adoption of the Cotton Best Management Practices Program, improved tail water return systems, restrictions placed on endosulfan use and the introduction of genetically modified *Bt* cotton have all reduced the movement of endosulfan into river systems. The drought over 2002–2008 would also have some influence as less area was cropped and lower volumes of chemicals applied. Similar results have been reported in the Gwydir and Macintyre Valleys 1992–2003 (Mawhinney 2004), 1994–2001 Queensland Murray Darling Basin (Waters 2004).

Figure 44 Median electrical conductivity ($\mu\text{S}/\text{cm}$) for three sites (Namoi River at Bugilbone, Mehi River at Bronte and Barwon River at Mungindi) located downstream of major cotton growing areas in each valley from 1991–92 through to 2001–02



Herbicides

Table 24 also shows the number and percentage of detections of common herbicides in the Namoi River between 1992 and 2007. The data indicates that the number of atrazine detections have always been high and increased in the last four years.

Atrazine is used on sorghum crops in the catchment, which have seen some increased plantings in response to higher grain prices. Metolachlor is a herbicide used for weeds in a range of crops including cotton, sorghum and sunflowers. Due to its high water solubility it is prone to transport by runoff and remains

Figure 45 Total endosulfan concentrations in the Namoi Catchment from 1991–1992 to 2006–2007

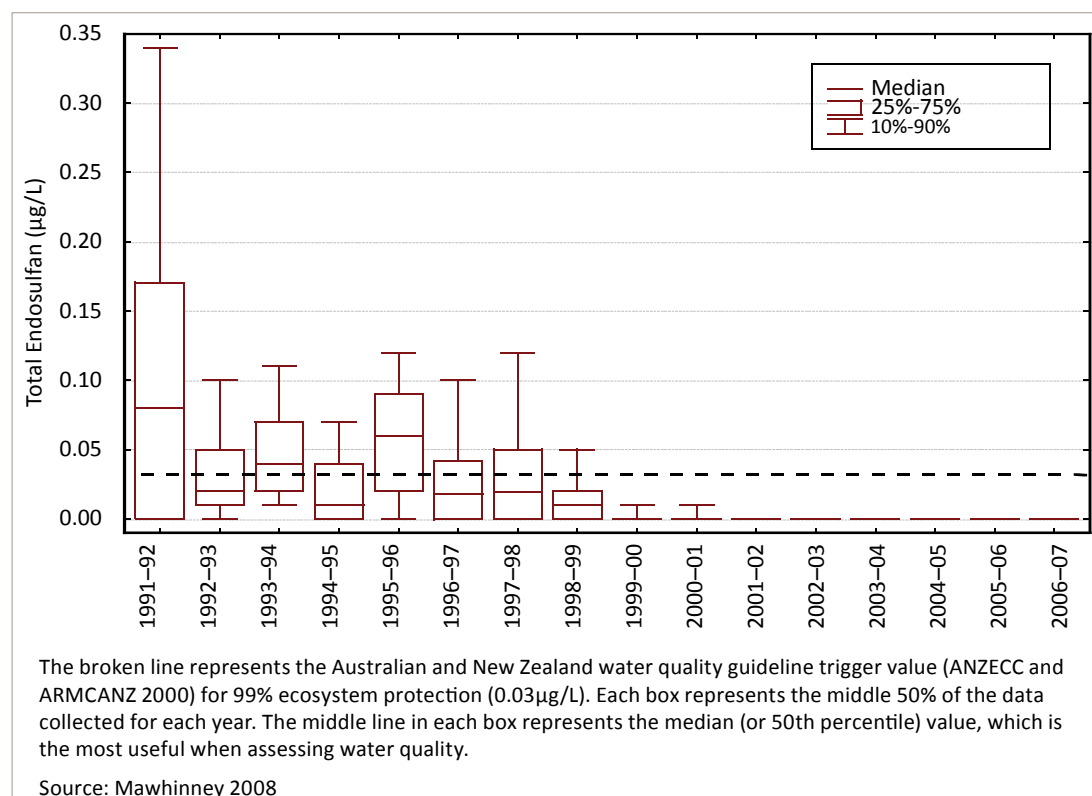


Table 24 Number and percentage of detections of common pesticides for all samples collected in the Namoi Catchment from 1991–1992 through to 2006–2007

YEAR	ENDOSULFAN	ATRAZINE	DIURON	FLUOMETURON	METOLACHLOR	PROMETRYN	NITROGEN
1991–92	43 (32%)	57 (43%)	11 (8.2%)	2 (1.5%)	0	10 (7.5%)	134
1992–93	47 (44%)	26 (24%)	4 (3.7%)	2 (1.9%)	0	3 (2.8%)	107
1993–94	34 (49%)	33 (48%)	3 (4.3%)	5 (7.2%)	10 (14%)	3 (4.3%)	69
1994–95	33 (37%)	19 (21%)	0	0	2 (2.2%)	3 (3.4%)	89
1995–96	41 (48%)	32 (37%)	1 (1.2%)	0	9 (10%)	4 (4.7%)	86
1996–97	75 (47%)	79 (49%)	4 (2.5%)	19 (12%)	15 (9.4%)	12 (7.5%)	160
1997–98	69 (43%)	48 (30%)	12 (7.4%)	39 (24%)	30 (19%)	33 (20%)	162
1998–99	57 (35%)	73 (44%)	14 (8.5%)	23 (14%)	40 (24%)	7 (4.2%)	165
1999–00	20 (11%)	90 (51%)	11 (6.2%)	14 (7.9%)	38 (21%)	4 (2.2%)	178
2000–01	14 (7.8%)	98 (55%)	13 (7.3%)	40 (22%)	44 (25%)	9 (5%)	179
2001–02	0	16 (14%)	4 (3.4%)	4 (3.4%)	5 (4.2%)	5 (4.2%)	118
2002–03	0	21 (19%)	3 (3%)	7 (6%)	3 (3%)	1 (1%)	112
2003–04	0	63 (62%)	3 (3%)	6 (6%)	11 (11%)	2 (2%)	102
2004–05	8 (7.8%)	58 (57%)	1 (1%)	4 (3.9%)	27 (26%)	5 (4.9%)	102
2005–06	0	67 (64%)	1 (1%)	9 (8.6%)	14 (13%)	8 (7.6%)	105
2006–07	0	50 (71%)	3 (4%)	2 (3%)	7 (10%)	2 (3%)	70

Source: Mahwinney 2008

a commonly detected herbicide. Diuron is a herbicide used in cotton and other crops and is strongly bound to clay particles and organic matter. Since 2002 there have been less detections of Diuron. Fluometuron and prometryn are used mostly in cotton and their frequency of detection have also fallen since 2001.

The introduction of Roundup Ready® cotton varieties in the 2001–2002 season has seen a decline in the detections of herbicides such as diuron, fluometuron, metolachlor and prometryn as cotton growers become more reliant on glyphosate for weed control. However, 2002–2007 seasons have been drier thus a definitive link of these trends to Roundup ready cotton is not conclusive.

Water quality on-farm monitoring on cotton farms

Water quality of groundwater bores is generally checked when the bores are installed. Groundwater quality in cotton regions has recently been reviewed in 2006 by The University of Technology, Sydney and the reports can be found on the Cotton Catchment Communities CRC website. Water quality information on farms is not collected regularly by growers. One comprehensive data set reported from the Gwydir valley for 1998–2001 (Montgomery and Faulkner 2004). A smaller Honours project at UNE was undertaken at Dirranbandi during the summer of 2001–02 by Smith and Roth (2004).

A further pilot study was undertaken between October 2005 and March 2006 in the Namoi valley. Two hundred water samples were collected from 10 farms at monthly intervals. Samples were taken from the Namoi River, a groundwater bore and a water

storage on their farm. Table 25 shows the average of key data for the river, groundwater bores and on-farm water storages over the sampling period. The river water showed values typically collected by other studies and confirmed the water's good quality. The bores had a slightly higher EC, Cl, Na levels and lower sulphur levels than the river. These bores all had good quality water. The on-farm water storage data, as expected, was a mixture of both river and ground water, as well as additional sediments from tail water recycling following crop irrigations. The higher nitrate levels in the storages would be the result of fertiliser application, which was a similar finding to the Dirranbandi study (Smith and Roth 2004).

Following the 2005–06 season, the cotton industry benchmark survey found 79% of growers did not collect water quality information, with only 4% measuring EC levels (CCA 2007a). The survey also asked if growers thought water quality monitoring was important for their farm operation and 57% said it was with the balance either ambivalent or disagreeing with the statement. The 2006–07 cotton industry benchmark survey found most growers do not collect water quality information for either groundwater (64%) or surface water (75%) (WRI 2007a). They found less than 20% were monitoring water quality attributes such as EC, SAR, and pH.

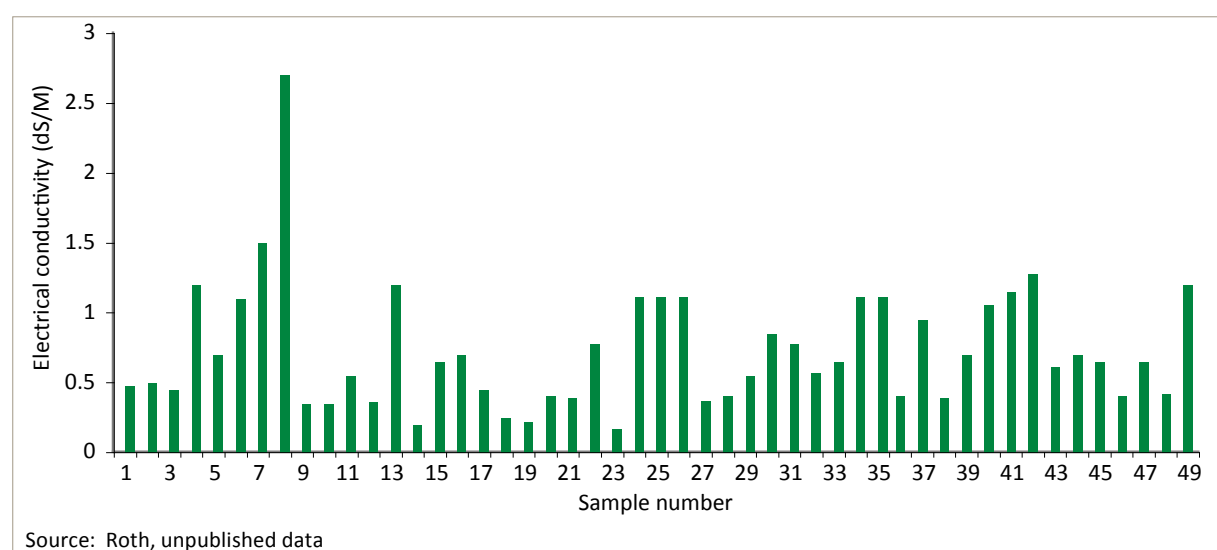
As an example Figure 46 shows the electrical conductivity data of 49 water samples that growers from the Namoi, Emerald, Dirranbandi, MacIntyre, Gwydir and Macquarie regions brought to a field day in 2002 on salinity and sodicity at Narromine, NSW. The data shows the majority of bores had low salinity levels, but

Table 25 Namoi water quality of 10 cotton farms

	pH	EC	Cl	Ca	K	Mg	Na	P	S	NO ₃
	pH	µS/cm	µg/mL	µg/mL	µg/mL	µg/mL	µg/mL	µg/mL	µg/mL	µg/mL
River	7.8	314.9	19.9	19.3	3.8	13.5	24.9	0.1	7.8	0.3
Bores	7.6	460.8	37.3	13.9	2.0	9.2	74.0	0.1	4.1	0.8
Storages	8.1	338.6	20.9	13.0	4.2	10.5	44.1	0.1	6.8	1.2

Source: Roth unpublished data

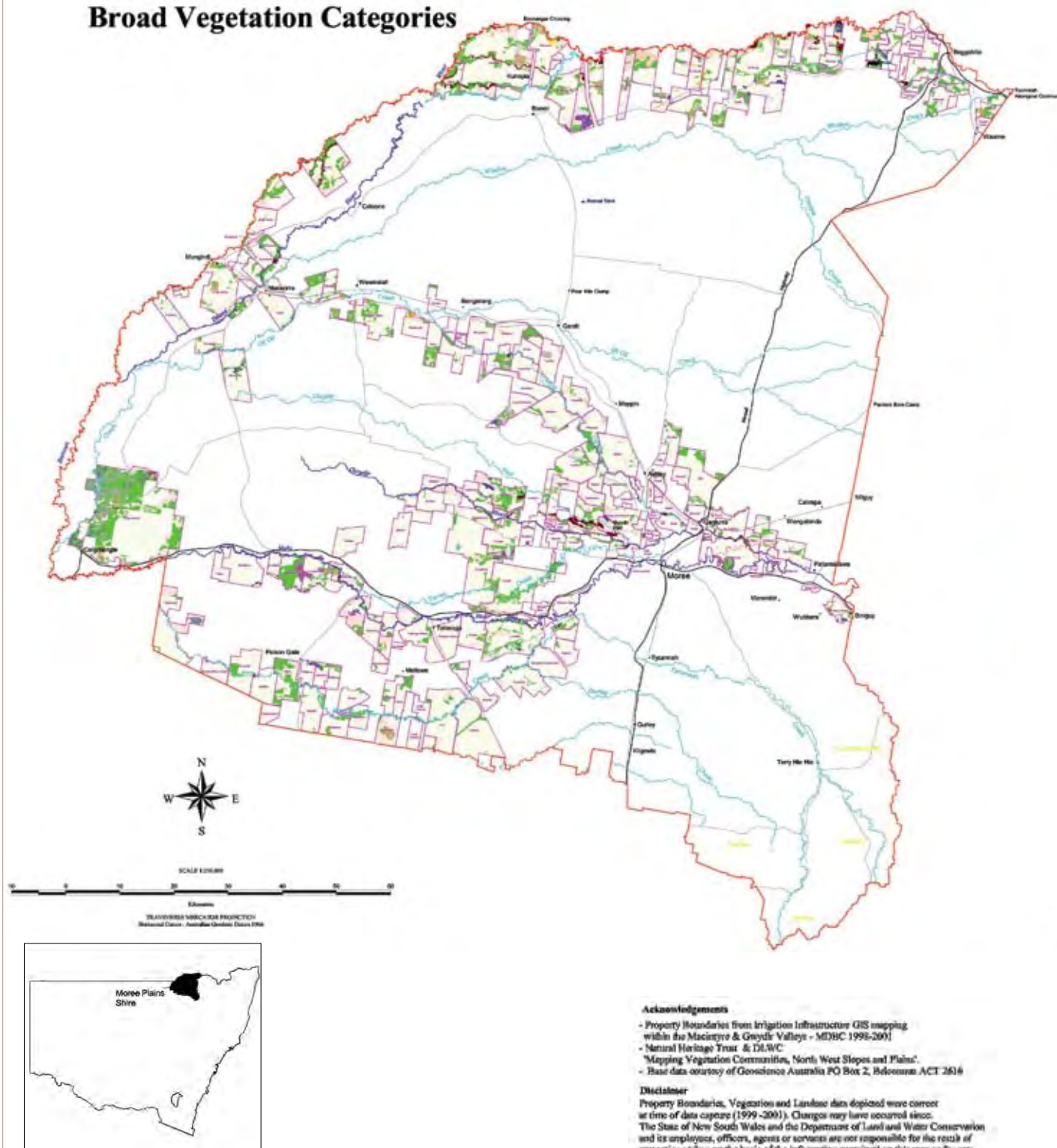
Figure 46 Water quality from 49 cotton grower's sites at the farming Systems Forum, Narromine December 2002



Source: Roth, unpublished data

Figure 47 Vegetation communities for cotton farms in the Moree Shire (1996)

Map Products for Cotton Biodiversity - Moree Plains Shire: Broad Vegetation Categories



Source: Map produced by the NSW Department of Land and Water Conservation for the Cotton Research and Development Corporation

Legend

Localities

- Town
- Locality
- Mountain
- Tank

- Moree RVMP boundary
- Property Boundary & Name

Rivers

- Creek
- River

Roads

- Highway
- Road
- Railways

Lgd	Vegetation	Area (Ha)
	BARADINE GUM	27
	BARADINE GUM/RIVER RED GUM	66
	BELAH	1892
	BLACK BOX	1203
	BLACK BOX/COOLIBAH	2533
	BRIGALOW	185
	BRIGALOW/BELAH	44
	BUDDA	141
	BULL OAK/BELAH	11
	CARBEEN	75
	CONTINUOUS CROPPING	249169
	COOLIBAH	38297
	COOLIBAH/BELAH	5333
	COOLIBAH/EURAH	269
	COOLIBAH/MYALL	175
	COOLIBAH/POPLAR BOX/BELAH	5
	COOLIBAH/RIVER COOBA	4665
	CYPRESS/POPLAR BOX	66
	EURAH	51
	GRASSLAND	47608
	LEOPARDWOOD	68
	LEOPARDWOOD/WHITEWOOD	39
	MYALL	139
	MYALL/ROSEWOOD	32
	OTHER	18064
	POPLAR BOX	7640
	POPLAR BOX/BELAH	1523
	POPLAR BOX/BRIGALOW	12
	POPLAR BOX/BUDDA	536
	POPLAR BOX/BUDDA/WILGA	551
	POPLAR BOX/CARBEEN	163
	POPLAR BOX/COOLIBAH	1517
	POPLAR BOX/LEOPARDWOOD	2
	POPLAR BOX/WHITEWOOD	14
	POPLAR BOX/WILGA	291
	RIPARIAN COMPLEX	5
	RIVER COOBA	644
	RIVER RED GUM	987
	RIVER RED GUM COMPLEX	3949
	RIVER RED GUM/CARBEEN	3
	RIVER RED GUM/COOLIBAH	5514
	RIVER RED GUM/COOLIBAH/BELAH	98
	RIVER RED GUM/COOLIBAH/RIVER COOBA	1
	ROSEWOOD/COOLIBAH	165
	SAND RIDGE - AEOLIAN	297
	SAND RIDGE - FLUVIAL	197
	SILVER LEAVED IRONBARK	4
	SILVER LEAVED IRONBARK/POPLAR BOX	9
	SILVER LEAVED IRONBARK/POPLAR BOX/PINE	9
	STANDING DEAD TREES	252
	WETLAND	464
	WHITE CYPRESS	9
	WHITE CYPRESS/CARBEEN	19
	WHITEWOOD	173
	WILGA	25
	WILGA/LEOPARDWOOD	10
	WOODY SHRUBLAND	312

there were several that recorded EC levels above 1dS/m. The major conclusion is the water quality, in particular groundwater varies markedly from site to site and the only way a grower will know is by undertaking some water quality measurements.

Constructed wetlands have been proposed as a means to reduce the risk from agricultural chemicals by removing pesticides through a complex range of ecological processes (Rose *et al* 2006). These wetlands or channels could improve the water quality. Aquaculture research is also underway to investigate value adding to water use as it is being used for irrigation. Water quality is a key issue for successful aquaculture facilities. A possible vision for the future irrigation storage by 2020 might include a polymer monolayer to reduce evaporation during the summer months, some aquaculture to value add economic returns, and some wetland vegetation to improve water quality and biodiversity.

BIODIVERSITY AND RIPARIAN LAND

Introduction

The intensification of agriculture and subsequent land clearing and use of pesticides has impacted on regional biodiversity. These impacts of the cotton industry on biodiversity have changed with time. During its early phases of expansion, land clearing, which at the time was being encouraged by the Government and the community was the major impact causing habitat loss. During the 1980s through to about 1995 the cotton industry had been the subject of extensive public criticism for its environmental performance. The principal issue causing concern was pesticide use and fish kills in the major river systems. Since about the year 2000, the major issue causing public concern has been water extraction for irrigation and its impact on aquatic biodiversity and wetland health.

Biodiversity

Biodiversity refers to diversity of genes, species and ecosystems. Its importance for the cotton industry was reviewed by Reid *et al* (2003). Scientists have raised the awareness of the importance of biodiversity, but at this stage there are more questions than answers when it comes to practical and local information in regional areas. The three principle threats to biodiversity are habitat loss, habitat modification and the introduction of exotic pests. Biodiversity is also negatively impacted through the use of pesticides, both insecticides and herbicides. There have been no systematic surveys of biodiversity on cotton farms, but there have been a number of relevant studies for other purposes and general observations and these have been collated by Reid *et al* (2003). Assessing the status of biodiversity is not easy and has proven challenging to value in an economic sense.

Biodiversity provides a number of ecosystem services that underpin cotton production in many direct or indirect ways. Ecosystem services are benefits people derive from the environ-

ment. Reid *et al* (2006) summarised 12 examples of ecosystem services important for cotton production which included:

- Natural pest control;
- Pollination;
- Maintenance of soil health;
- Water filtration;
- Prevention of soil erosion;
- Waste absorption;
- Maintenance of river flows;
- Maintenance of groundwater levels and quality;
- Maintenance and regeneration of habitat;
- Provision of genetic resources;
- Regulation of climate; and
- Provision of shade, shelter and barrier effect.

The journey to preserve or enhance biodiversity needs to begin with simple achievable goals, and become more complex and consolidated over time. Cotton farms generally occupy less than five percent of the land area in most catchments. However, the cotton industry occupies some of the most economic and biologically productive land that could be highly productive for biodiversity outcomes. On many cotton farms, twenty to thirty percent of the land is not used for cotton production so there is considerable opportunity to conserve and enhance biodiversity.

An enormous gap exists between the expectations of policy documents and what is known about the biodiversity “down on the farm”. Very little is known about biodiversity on private land in western cropping regions where cotton is grown. There is a need to find good biodiversity indicator species such as vegetation, birds or insects species, which will not only be useful indicators of biodiversity, but will also capture the hearts and minds of landholders as well. If landholders are aware and interested in a species they are far more likely to change their management practices in favour of that species. The level of native vegetation is one practical indicator of biodiversity.

Native vegetation

Native vegetation (trees, shrubs and grasses) provides critical habitat for a wide range of species to exist. For cotton production, it provides habitat for beneficial insects for integrated pest management, predator bats, and regulates groundwater levels. It is recognized as a carbon sink, which could have a direct economic value for farmers participating in carbon trading of emissions in the future. Most cotton farms have large areas of grassland, remnant vegetation and riparian zones not used for cropping. There is currently little data on the levels of these areas on cotton farms, thus a preliminary investigation for this study was conducted as a starting point. The data was obtained from the Department and Land and Water Conservation and processed by their vegetation mapping unit. On average, about 32% of cotton farms consisted of native vegetation in 1996 for the 196 cotton farms in the Moree Shire (Roth unpublished data) (Figure 47, on pages 52 and 53). The Moree Shire produces about a quarter of Australia’s cotton as there are a number of large farms in the region.

The 2005–06 cotton industry benchmark survey found that 14% (on average 446 ha) of cotton farms comprised native vegetation (CCA 2007a). The 2006–07 benchmark survey found 21% of the farm areas was native vegetation (912 ha) (WRI 2007a). The higher percentage figures in the Moree Shire are not surprising when compared to a national survey, which included regions like the Darling Downs and the Breeza area where native vegetation areas are much less.

The area of native vegetation is only part of the story. The quality and complexity of the vegetation is also a critical component and a number of vegetation indices have been developed, which are discussed for cotton farms in Reid *et al* (2006) and Cleland (2008). Whilst some of these indices have been designed so they are easy to do, it is unlikely a typical farmer will use them unless some assistance is provided by a natural resource management body.

Land clearing

Land clearing of remnant vegetation can have an impact on the sustainability of a farm or region. It is the single largest threat to biodiversity, which is why restrictions on land clearing have been put in place by State Governments. It causes loss of habitat, wildlife and soil.

Land clearing figures specifically for cotton farms or any other agricultural commodity are not readily available. An alternative indicator of stewardship could be breaches related to land clearing restrictions and regulations. The second environmental audit of the cotton industry found 2 out of 12 farms visited had cleared 200 and 500 ha in the last 10 years. They found in NSW land clearing was less prevalent where the majority of farms inspected had not cleared any land in the last 10 years (GHD 2003). The audit found that of the farms inspected over 80% had retained pockets of vegetation.

The cotton industry benchmark survey 2005–06 found the dominant strategies used by growers to manage native vegetation was 43% fenced and selectively grazed, 41% left it undisturbed, 39% did not graze it, 28% used continuous grazing, 28% controlled weeds/pests, 23% had planted native trees/vegetation, and 21% controlled regrowth (CCA 2007a).

Wildlife

There is a diverse range of wildlife on cotton farms, which is aided by the presence of water in rivers, billabongs and irrigation infrastructure. The wildlife includes insects/spiders, birds, fish, frogs, bats, reptiles and small mammals. Kangaroos, wallabies and emus are very common. Invertebrate species in the soil, water and land are also extensive. There are also common feral animals including wild pigs, cats and foxes.

Birds

Birds have frequently been proposed as indicators of biodiversity due to their ease in surveying and responsiveness to environmental parameters, especially vegetation condition and complexity (Freudenberger and Drew 2001). It is not clear whether bird species are decreasing or increasing in established cotton farming systems as there have not been any regular monitoring studies. There is anecdotal evidence of more birds around farms

as a result of the high adoption of transgenic cotton and less use of pesticides in recent years. Recently, some benchmarking studies have been undertaken on cotton farms, which can be used as a basis for future monitoring.

A baseline study of water bird abundance associated with on-farm water storages was conducted in the lower Gwydir valley during 1999–01 (Jarman and Montgomery 2002). Over 42,000 birds were counted, representing 45 species. Four of the 8 water bird species listed on Schedule 2 of Threatened Species Act (magpie geese, blue billed duck, freckled duck and Australian bittern) were found in low numbers on the farm water storages. The water bird community included ducks, pelicans darters, cormorants, herons, egrets, spoonbills, ibises, coots, and some water hens. The study found very few water birds bred on the irrigation storages and found significant differences between sites with those storages featuring trees, logs, vegetation, mud islands and other diverse habitat having the most wildlife.

Partridge (2004) conducted a bird survey of 19 sites of remnant vegetation on cotton farms near Moree and found 59 species of birds. A bird survey in the Namoi valley recorded 55 species in tree plantings (less than 10 years old) on cotton farms in the Namoi Valley (Smith 2005). A bird survey of woodland birds was commissioned by Rural Lands Protection Boards of the Northern Slopes of NSW on the travelling stock routes, which weave their way through areas where cotton is grown. They found 130 species (Freudenberger and Drew 2001). West of Wee Waa in the Namoi valley, Cleland (2008) surveyed birds across 27 sites on cotton farms between 2006–2008 and found 153 bird species, including 8 of the 12 indicator species recommended by Ford and Thompson (2006). Those 8 identified indicator species found were the Eastern Yellow Robin, Grey-crowned Babbler, Spiny-

cheeked Honeyeater, Striped Honeyeater, White-winged Fairy-wren, Variegated Fairy-wren, Brown Treecreeper and Purple Swamphen.

The grey crowned babbler (*Pomatostomus temporalis*) pictured below) is one of the possible indicator species promoted for monitoring as it is easy to identify, medium size and usually in groups. The species has become extinct in coastal Victoria, South Australia and parts of southern NSW/ACT. However, it is still reasonably common in areas where cotton is grown because of the large tracts of remaining native vegetation. The choice of an appropriate water bird such as the purple swamp-hen could also be another useful indicator as growers are more likely to notice these as they drive around their farms and irrigation infrastructure.

Bats

Research has shown that many small insectivorous bats have been found in around cotton crops and feed on the pest moth *Helicoverpa* spp. and other species. Fifteen species were recorded in autumn 2003 (MacKinnon 2005). The problem with using bats as indicators is that they are not easy to find or observe, as they are mostly active at night.

Insects and other invertebrates

Cotton crops attract a large number of invertebrates, including benign, pest and beneficial species. Fitt and Wilson (2002) recorded 400 species in 1994–95 summer and 450 species of invertebrates in one field during the 1995–96 summer. The cotton industry Integrated Pest Management Manual has lists and photographs of the most common pest and beneficial insects (Deutscher *et al* 2004). The difficulty of using insects and other invertebrates as biodiversity indicators include the significant



Grey crowned babbler, near Narrabri NSW

time collecting species and challenges with species identification. The advantage of using insects as indicators is that insect scouting has been part of the culture of cotton agronomy and there would be some excellent data sets.

Fish

Given the proximity of the cotton industry to water bodies, fish could be good indicators of biodiversity and river health. State agencies have some data sets, which they are hoping to improve in the future. Fish would not be easy indicators for individual landholders to collect as they are difficult to sample, although some fishing observations could be recorded.

The riparian zone

Riparian land is any land adjacent to a river, creek or wetland and is critical for water resource management. The riparian vegetation protects the banks from erosion, acts as a filter strip to trap sediment and nutrients. It provides shade which impacts on light and temperature of the stream, provides habitat and food for in stream organisms and animals and plants that live near rivers, which are all closely linked with water quality. The crucial factors for a healthy riparian area are vegetation, which should be managed for diversity and structure (groundcover, understory and over storey), width and longitudinal extent (Riding and Carter 1992).

Although cotton farms occupy less than five per cent of the catchment areas in which they operate, they are generally located adjacent to rivers and riparian areas as shown in Figure 47 where the farms can be seen adjacent to the Mehi, Gwydir and Border Rivers. In the 2005–06 Cotton industry benchmark survey, 70% of growers reported they have stream or river frontage (CCA 2007a). The 2005–06 cotton industry benchmark survey found the dominant strategies used by growers to manage creeks and riparian areas were fencing and selectively grazed (51%), not grazed (40%), continuous grazing (14%), control weeds/pests (21%), provide alternative water points for stock

(21%), maintain filter and buffer strips near the area (18%), and planted native trees/vegetation (15%) (CCA 2007a).

The photograph below, left shows a section of the Gwydir River, north west of Moree. The prominence of the riparian corridor is clear, as is the close proximity of the cotton and grain fields to the river. This corridor has complex vegetation (understory and over story over the river). It also shows the importance of connected corridors for wildlife, nature's highway.

The second environmental audit of the cotton industry by GHD (2003) found most cotton farms had cotton fields within 100 metres of creeks or rivers and reported some earlier published figures from Government agencies supporting this observation more broadly. The audit recommended riparian management as an area for improved management.

In response, a publication was produced by the Cotton Research and Development Corporation on "Managing riparian lands in the cotton industry" (Lovett *et al* 2003). The publication raised awareness of riparian land concepts of growers and industry leaders, and led to the inclusion of riparian land management in the Cotton BMP Program. A summary of the main findings of a case study follows; others were reported by Roth (2003).



Left: the Gwydir River, north west of Moree, showing a clear riparian corridor



Right: Research has found microbats to be a significant predator of *Helicoverpa* moths and other insect pests

Reducing bank slumping and pesticide contamination

John and Robyn Watson
Kilmarnock, Boggabri, NSW

In 1995, the Watsons started a program of improving riparian areas as they were concerned about bank slumping and pesticide contamination of the river. They identified the places where action was needed along the seven kilometres of river that runs through their property and worked to rehabilitate these areas. Most of the work involved planting a mix of native grasses, shrubs and trees to stabilise the riverbank and prevent erosion and loss of valuable land. John and Robyn also kept their cattle out of riparian areas as they were causing a lot of damage to the riverbank and increasing erosion.

Some of the lessons John and Robyn wanted to share with other cotton growers are:

- do not try to do too much at once. Pick your sites and do a little every year as conditions allow;
- exclude stock if you have them. Once the area has been rehabilitated light grazing is okay, but do not let in bulls!
- do not think that you have to use expensive machinery to restore riverbanks. You can do a lot with plants and repair steep banks without spending a lot of money;
- the ideal time to plant trees is when there is moisture in the bank, such as from a “fresh” in the river. On steeper banks, use long stem stock for seedlings (up to one metre high). The species they have had most success with are river red gum, casuarina and river cooba;
- planting native grasses is very important for stabilising the toe of the bank. The grasses used are phragmites at water level, Queensland cane grass in the middle of the bank and native vetivia a bit higher up. Once established, other grass species naturalise around them;
- weed management is important;
- do not water unless it is really dry;
- grow your own plants by collecting the seeds from those areas along the riverbank and on the property that are regenerating or protected. Use local tree stock as it is native to the area and most likely to survive; and,
- use riparian buffers between the riverbank and cotton paddocks as this protects the river from spray drift as well as trapping sediments and nutrients running off the paddocks.



Top: Robyn Watson on the revegetated river bank

Below: The Namoi River before (centre) and after (bottom) riparian revegetation works at Kilmarnock, Boggabri

INSECT, WEEDS, PESTICIDE USE AND PESTICIDE RESISTANCE

Weeds

Weeds present a sustainability risk to growers as they can make it uneconomic to grow crops or they pose an environmental risk to the broader catchment. As cotton farming systems have changed, so has the weed spectrum. An overview on weeds of cotton and their management can be found in the WEEDpak manual (Australian Cotton CRC 2002).

Surveys of weed density and diversity were undertaken in 1992, 1996 and 2001 by Charles *et al* (2004). They found a reduction in average weed density from 1.84 weed per metre to 0.51 weeds per metre. A total of 54 weed species were identified. The density of weed species changed over time. For example, sesbania and yellow vine can be directly related to the introduction of a new herbicide, Staple® in 1996. By 2001, 14 of the 20 most common weeds of cotton were either glyphosate tolerant, or favoured by reduced cultivation.

Charles *et al* (2004) also asked growers which were the most troublesome weeds in 1989, 1996 and 2001 and have listed the 15 most troublesome weeds for each of those years. Some of the most troublesome weeds included cow vine, bladder ketmia, noogoora burr, nutgrass, barnyard grass, yellow vine, wild gooseberry, ryncho, and sesbania. Their relative importance has changed over time. For example, nutgrass which was weed number 10 in 1992 became weed number 1 in 1996, but by 2001 following the introduction of Roundup Ready® cotton it became less troublesome (number 5).

Roundup Ready® cotton was first used during the 2000–01 season and Roundup Ready Flex® with its longer spraying window first available in 2006–07. These cotton plants contain a gene that confers tolerance to glyphosate herbicides. There has been widespread adoption of Round Up Ready® cotton in Australia (about 74% (2006) & 83% (2007) of the total industry

crop area (Adam Kay, pers. comm. 2008)). This is reducing the use of pre emergent herbicides to those with greater reliance on post emergence application (Taylor *et al* 2006). It is causing a further species shift in weeds to those more tolerant of glyphosate. For example, a weed that is having increasing impact is fleabane (*Conza bonariensis*). Another is sow thistle (*Sonchus oleraceus*).

WRI (2008) surveyed cotton consultants following the 2007–08 season. Consultants were asked to indicate the changes they had seen in the prevalence of weed species since 2003. Respondents indicated that fleabane (93%) and volunteer cotton (88%) were more prevalent than in 2003. A smaller number (about 25%) of respondents also indicated that the prevalence of peach vine, bell vine, bladder ketmia, and barnyard grass had increased. These species shifts will need to be monitored and managed into the future.

The greatest benefit of Roundup Ready® cotton has been the ability to grow crops where there are excessive weeds, especially nutgrass. The other advantage has been greater early season seedling vigour enhanced by less use of residual herbicides. The 2006–07 survey of cotton consultants found since its introduction Roundup Ready® cotton has changed farming practices with:

- 78% less manual chipping;
- 46% less inter row cultivation; and
- 46% less use of residual herbicides Source WRI 2007b).

The development of resistance to herbicides by weeds is a sustainability risk. Over reliance on Roundup® (glyphosate) will lead to future resistance problems. Glyphosate resistant rye grass and barnyard grass have been reported in the Australian cotton growing area (Charles 2008). There are resistance management plans for glyphosate and other herbicides, which include a range of integrated weed management techniques.

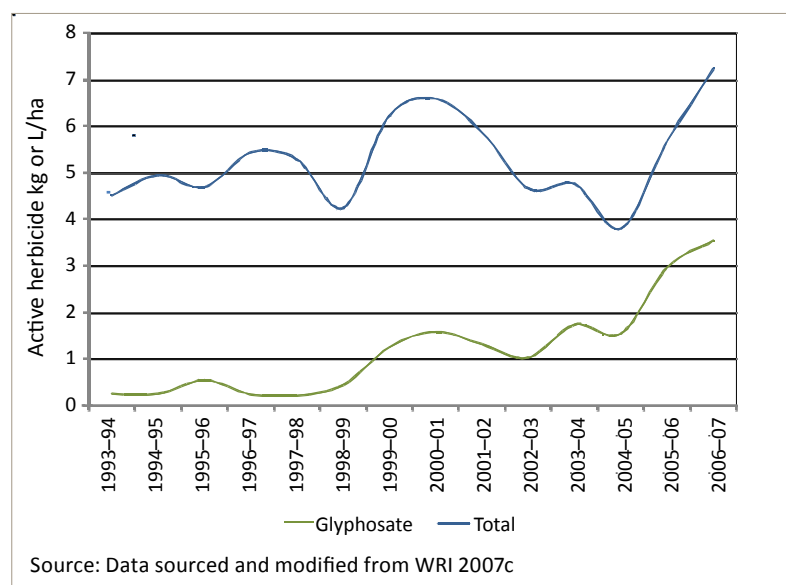
Herbicide use

The total herbicide use and glyphosate herbicide use in Australian cotton fields between 1993–2007 is shown in Figure 48. Herbicide use peaked in 2000–01 and declined for several

years as a result of some new herbicide products and a more integrated weed management approach. Since 2004–05 there has been a dramatic increase in the total use of herbicides coinciding with the introduction of Roundup Ready® Cotton and greater use of Roundup® (glyphosate) herbicide.

However, the use of some environmentally problematic herbicides such as trifluralin (Treflan®), and Diuron® (Figure 49) and Cotogard® (fluometuron, prometryn) (not shown) has dropped significantly. Since 2001–01 Diuron® and trifluralin use has dropped about 80%. Research is continuing on the use of environmental impact quotients so that the environmental impact of different pesticides can be compared, rather than just quantities of use (Peter Gregg, pers. comm. 2008). An environmental risk comparison of Roundup® and other herbicides was completed by The University of Sydney, which concluded that Roundup posed a lower environmental

Figure 48 Total herbicide use and glyphosate herbicide use in Australian cotton fields 1993–2007



risk compared to other herbicides used in conventional cotton systems (Crossan and Kennedy 2003).

The use of herbicides on irrigation channels is a common practice. The amount of herbicide used has fluctuated between 0.5 – 2 kg or litres /ha between 1993 and 2007 (WRI 2007c). Generally the amount of product used on channels is less in seasons with little rain.

Environmental weeds have also been raised by catchment managers as worthy of mention in sustainability reports. Lippia (*Phyla canescens*) is becoming a major weed of floodplains in the Murray Darling Basin and can be found on many cotton farms, but its presence is not related to cotton production. Its presence is often associated with poor pasture and grazing management. A summary on lippa ecology, distribution and impacts can be found in Earle (2003).

Insect management

Insect management has traditionally been the major problem and cost of growing cotton in Australia and around the world. Cotton is attacked by a diverse group of pests, of which the *Helicoverpa armigera* and *Helicoverpa punctigera* species are dominant (Fitt and Wilson 2002). Other pests include thrips, aphids, mirids, spider mites, green vegetable bug, and silver leaf whitefly. Some common beneficial predators include ladybirds, assassin bug, hoverfly, spiders, trichogramma wasp and others.

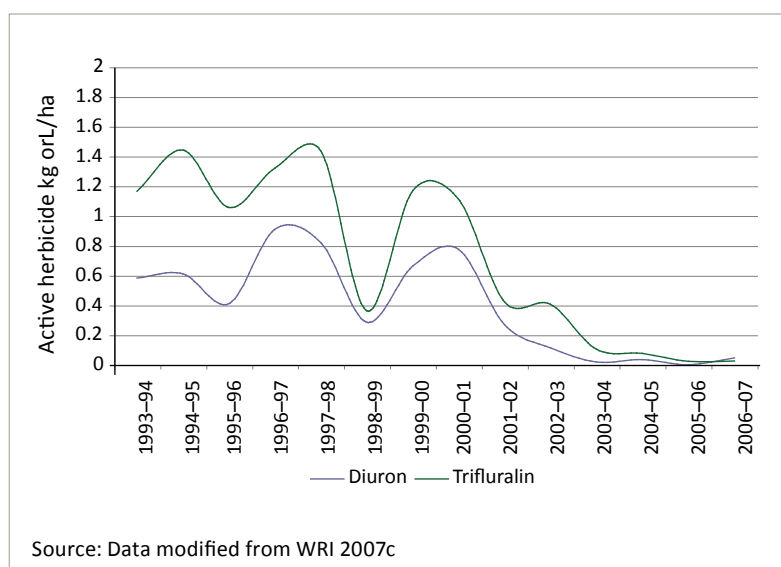
Pests were traditionally controlled with the use of insecticides that had a high cost, had non target impacts on the environment and killed beneficial predators resulting in secondary pest outbreaks. Integrated pest management guidelines have been developed for cotton production systems in Australia (Deutscher *et al* 2002). The guidelines provide details on growing a healthy crop, monitoring pests and beneficial predators, how to prevent resistance, managing weeds, managing other crops in the landscape, and the use of transgenic cotton varieties. Integrated pest management changes have included softer chemistry options,

use of beneficial predators, avoiding broad spectrum pesticides, changing management thresholds and the use of transgenic cotton varieties. The Cotton Pest Management Guide contains the latest thresholds, products, and techniques for managing specific pests (Farrell 2009). Coutts *et al* (2003) found that the principles of IPM had a wide level of acceptance throughout the cotton industry. Over the last five years, 35–50% of consultants adhered to the guidelines all of the time, while 30–50% did so most of the time (CCA 2008).

The major change in insect management over the last decade has been the introduction of transgenic cotton varieties. Transgenic cotton was first grown commercially in Australia in 1996–97 with release of a *Bacillus thuringiensis* (Bt) cotton known commercially as Ingard®. The area of transgenic cotton planted was capped by regulators. The cap was initially 10% in 1996–97, and was increased to 30% in 2000–01 until 2003–04 when Ingard® varieties were completely replaced with two Bt gene varieties, known commercially as Bollgard® and the cap was removed. Since the removal of the planting area cap there has been a rapid adoption of transgenic Bt varieties, which were 85% of the national crop in 2006–07 & 91% 2007–08 (Adam Kay, pers. comm. 2008). The implementation history and key issues of transgenic cotton in Australia is described by Fitt (2003) and Pyke (2007).

The annual quantities of insecticides and acaricides applied to the Australian cotton crop in kg of active ingredient per hectare between 1995–96 and 2006–06 is shown in Figure 50, on the following page. There has been a large reduction in the amount of pesticides used to the lowest levels on record. The two outliers from the curve were years of high insect pressure (1998–99 & 2003–04) associated with above average rainfall. Another consideration has been the drought and related lower pest pressures, which means there has also been less secondary pests requiring management (Gregg and Wilson 2008). Over the four seasons 2002–03 to 2005–06, average insecticide usage was 82% less on Bollgard® crops than on conventional cotton crops.

Figure 49 Diuron and trifluralin use in Australian cotton fields 1993–2007



Bollgard® crops currently receive less than one spray per hectare compared with 7–11 sprays on conventional crops (Pyke 2007).

Growers have adopted Bollgard® varieties because of perceived economic and environmental benefits. Other benefits of using transgenic cotton varieties and less spraying have included life-style benefits and worker safety benefits (Pyke 2007).

There will always be a number of future challenges related to cotton pest management. Gregg and Wilson (2008) have suggested that the cotton industry is relying too much on Bollgard® technology. They suggest the industry reminds itself of the basic principles of IPM, that is not to become dependent on one approach, in this case the use of transgenes, but rather to use a range of approaches, including some new tools and products that will soon be available for commercial use such as biopesticides, semio chemicals, and new pesticides.

Insecticide resistance

Insecticide resistance is a major sustainability risk for the cotton industry. The management of insect resistance to transgenic cotton traits is perhaps the greatest potential immediate sustainability risk to the Australian cotton industry.

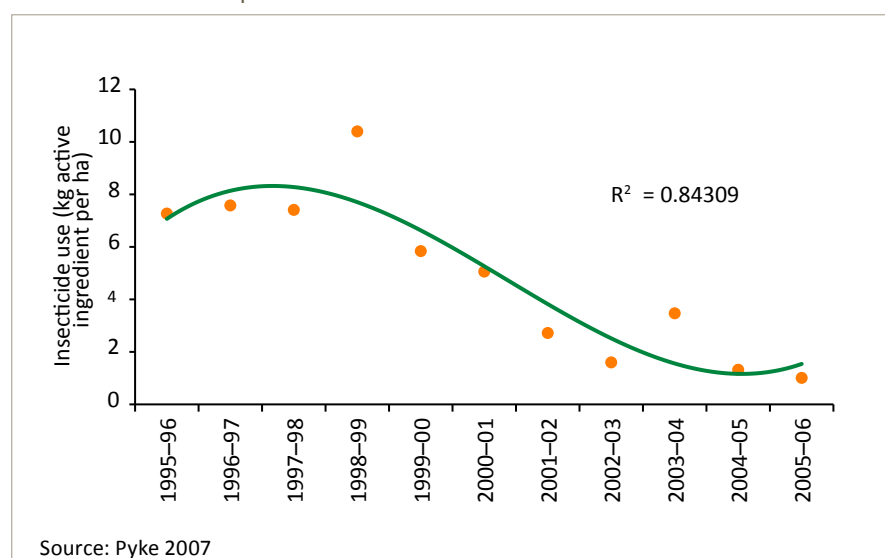
Resistance by the *Helicoverpa* spp. to insecticides caused major yield losses during the 1970s and 1980s and remains an important issue to manage. In response, the cotton industry developed an insecticide resistance management strategy, which has been in operation since 1983. This strategy has evolved over time with the development of new chemical products and insect management knowledge. The current version of the resistance management strategies is described in the cotton pest management guide 2008–09 (Farrell 2009). Other pests such as the two-spotted mite are notorious world-wide for developing insecticide resistance including Australia where resistance in cotton continues to evolve (Herron *et al* 2008). Aphid species have also developed resistance to certain products (Herron *et al* 2008).

Since the advent of Bollgard® cotton varieties, resistance to many insecticides has declined. In the last five years resistance for *Helicoverpa armigera* have decreased for spinosad (Tracer®), indoxacarb (Steward®), emamectin benzoate (Affirm®) and the synthetic pyrethroid bifenthrin (Talstar®) (Figure 51) (Rossiter *et al* 2008). However, the finding cannot be extended to all synthetic pyrethroids, for example, fenvalerate had high resistance levels. Monitoring for endosulfan, carbamates and organophosphates is also ongoing and the resistance levels were lower in 2007–08 than the previous year.

Should the *Helicoverpa* spp. develop resistance to the various transgenes, they could no longer be used and then the cotton industry would be forced to use conventional varieties, traditional chemical sprays and other integrated pest management techniques. It is difficult to forecast the grower response to a non transgenic cotton scenario, as it would depend on the prices of cotton and alternative crops, but it is possible some cotton growers may opt out of cotton and grow other irrigated crops because the risk and rewards are perhaps not as attractive as they were 15 years ago.

There is a transgenic *Bt* resistance monitoring program in Australia. Eggs and larvae are regularly tested for resistance. There have been no reports of field failures of Bollgard II® varieties due to resistance, however the data from 2007–08 F₂ tests show an increase in the frequency of *Cry2Ab* resistance alleles in *Helicoverpa punctigera* since the introduction of Bollgard II® (Downes 2008). The cotton industry is concerned about the high and potentially increasing frequency of *Cry2Ab* resistance alleles in populations of *Helicoverpa* species and has increased its resistance monitoring in the 2008–09 season.

Figure 50 Annual quantities of insecticide and acaricide applied to the Australian cotton crop between 1995–96 and 2005–06



CLIMATE CHANGE

Climate change, its implications for cotton production and management options have been discussed by McRae *et al* (2007), Howden (2008) and Bange *et al* (2009). These reviews provide a basis for continued discussion and a future action plan by the cotton industry. This plan will need to include mitigation (ie. reducing greenhouse emissions) and adaptation options to the changing climate.

Cotton is adapted to hot climates, but research into the integrated affects of climate change (increased temperature and CO₂, and water stress) on cotton growth, yield and quality need further analysis. Likely scenarios include increased CO₂ levels may increase photosynthesis and water use efficiency leading to higher yields in the absence of water stress, increases in atmospheric evaporative demand may increase water use in well watered crops and increase the impact of stress when water is limited, temperature increases at the start and end of seasons may have a positive effect on yield by extending time for cotton growth, and an increase in the frequency of days with very high temperatures will negatively impact on both growth and development. Insect pest and disease ecology will also be impacted and need consideration.

The major risk and unknown factor is what will happen to rainfall and hence water availability for irrigation. Regional specific effects will need to be assessed thoroughly as the predominant cotton production regions span from southern NSW to north Queensland. The predictions are clearer for the north and southern extremities of the cotton industry, but the models are less clear on rainfall trends for the main cotton belt of northern NSW and SW Queensland.

SUMMARY

There have been significant improvements in the management of natural resources by the cotton industry, particularly in the last decade.

Soils

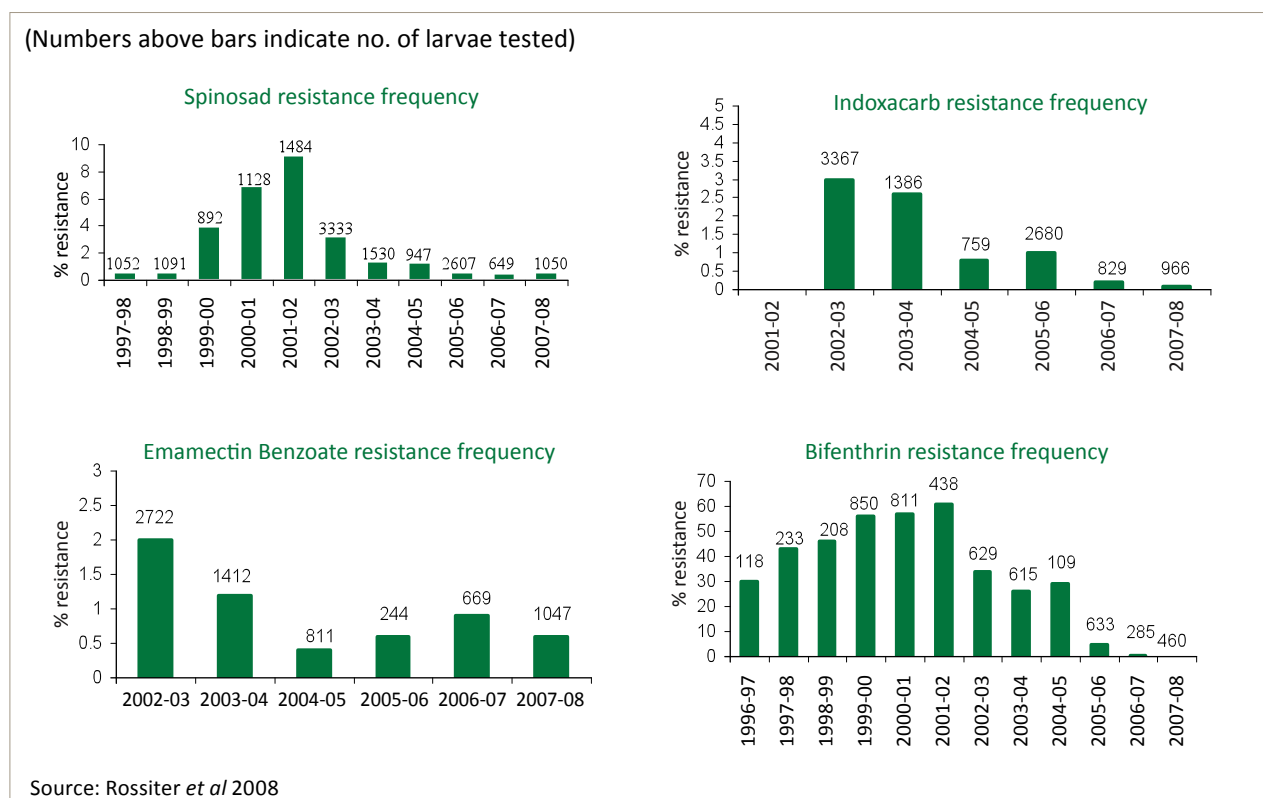
There has been a reduction in soil tillage, widespread adoption of controlled traffic systems, the use of permanent bed farming systems, and less raking and burning of stubble. This has resulted in less soil compaction and improved soil physical structure.

As cotton yields continue to rise, more nutrients are being removed from the farm. Nitrogen, phosphorus and potassium fertiliser rates are increasing in response to increased nutrient removal. Higher fertiliser rates does not mean that growing cotton is unsustainable; however, nitrogen rates now commonly exceed 200 kg N/ha and the sustainability of this practice is questionable.

The naturally sodic sub soils of many areas where cotton and grain crops are grown poses some difficult soil structure and crop nutrition management issues. The lack of soil carbon is another problem that needs to be improved as much as possible. Farmers will need to ensure they at least maintain, and preferably increase soil carbon levels.

Soil borne diseases such as Fusarium wilt and black root rot have become significant problems in some areas and indicate the farming system is not sustainable unless improved management practices are adopted. In the future, the greater attention to soil biology, and alternative approaches to improve fertiliser efficiencies will be required.

Figure 51 *Helicoverpa armigera* insecticide resistance frequency trends over time



Measuring soil attributes is not a new activity for most cotton farmers who have been using soil tests for many years for fertiliser decisions. Monitoring the long trends of soil testing data is not done by the majority of cotton growers. The soil monitoring case study showed that these attributes can be monitored with little additional effort and the results will be very site specific and vary from year to year in response to management.

There are many soil attributes that can be monitored for sustainability purposes. However, it is not possible for an agronomist or a cotton grower to collect and process all of these. One of the challenges is the identification of functions that are most responsive to management and easily measured. It will take some time for all the stakeholders to agree on a suite of soil monitoring attributes. There is no single indicator or soil test that will reflect general soil health. This will require a suite of indicators.

The most important and easily collected soil attributes are organic carbon, EC, Na (ESP%), and Cl which are all part of a standard soil test. At an industry scale, it is more difficult to monitor trends mostly because there is no data capture system. An ancillary problem is the volume of data. For example, a grower with 12 cotton fields would have 12 data sets. At the farm scale, the major challenge is cost (time) to collate the soil test data over time. The industry could fund a research project to kick start this process. It would make an excellent undergraduate student project, although the task is much larger than that.

Water

Irrigation water availability will remain the most limiting factor to cotton production in Australia. The key issues for cotton growers are availability, security, cost, and its quality. The key issue for both cotton growers and the community is the balance between environmental needs and other water users.

Cotton production does require irrigation water to obtain high and profitable yields. The main steps forward to improve water management to maximise crop yield per unit of water include:

- good agronomy (the continued use of improved cotton varieties, good soil management, crop rotations, crop protection, nutrition management);
- improving the delivery of water (from river or storage to the field);
- ensuring farm design is optimal for water delivery;
- maximising storage and distribution efficiency, reducing evaporation and drainage;
- maximising application efficiency;
- achieving uniform application;
- use of alternative irrigation systems such as centre pivots, lateral moves and drip (where applicable); and
- improved water measurement tools.

The cotton industry adopted a goal in 2006 to double its water use efficiency by 2015. Whilst the measurement of this goal will be difficult, the intent of the goal is clearly to significantly improve water use efficiency.

There is strong evidence that growers have improved their water use efficiency by 3–4% per annum, or at least 20% in last decade. There are also many individual examples of even more significant

improvements in one year as a result of irrigation system improvements. More and improved data for the 2008 and, 2009 seasons is needed to be sure these individual improvements are taking place industry wide. There is a large range and variability in reported water use figures and significant room for growers at the lower end to improve their practice. Water use efficiency reporting could also be enhanced with the reporting of median figures, rather than just averages,

Most water losses occur in on-farm conveyance and storage through seepage and evaporation in channels and on-farm storages. Seepage losses can also be high in poorly managed surface irrigation systems. Cotton growers relative to other industries have widely adopted the use of soil moisture sensors, but there is scope for greater adoption in the future. There will also be increased adoption of overhead systems (centre pivots and lateral moves) in the future, and a much smaller area of sub surface drip irrigation on specific soil types.

The water quality where cotton has been grown is generally very good, with the exception of some specific and few in number groundwater bores. This could explain why there has been very little water quality monitoring on farms; this issue is not well managed on cotton farms. Water quality fluctuates daily and annually and is influenced by nutrient load, sediment, rainfall/water flow and groundwater hydrology. It is also very site specific, especially groundwater. Fortunately, it is relatively easy and cheap to measure/monitor. It is recommended that water quality EC is monitored every year, with a full water quality analysis every few years. This water quality analysis should include EC, Na, Ca, Mg, Cl, SO_4 and HCO_3 . Groundwater bore levels should be monitored at least at the end and start of each irrigation season.

Biodiversity and riparian management

Biodiversity on cotton farms is aided by the presence of water in rivers, billabongs and irrigation infrastructure. Biodiversity is important for all species on earth and underpins cotton production in many direct or indirect ways such as integrated pest management, maintenance of soil health and water quality. A personal observation is that there is greater biodiversity species range and numbers) such as spiders, birds, and insects on cotton farms than there was a decade ago, due to the high adoption of transgenic cotton varieties and its association with less pesticide use.

Monitoring the status of biodiversity is not easy and there are many potential attributes that could be monitored. It is recommended the cotton industry begin with simple achievable indicators, that can become more complex and aggregated over time. Recommended biodiversity indicators include vegetation, birds, fish, mammals or insects species. If the biodiversity indicators also capture the hearts and minds of landholders they are far more likely to change their management practices in favour of the species. Most biodiversity monitoring will require a degree of external expert input and this could be achieved through small projects funded by natural resource management agencies.

Birds would make good indicators of biodiversity due to their ease in surveying and responsiveness to environmental parameters. Studies have found high numbers, 45–153 bird species, on cotton farms. The use of indicator species such as the grey

crowned babbler (*Pomatostomus temporalis*) could also help cotton growers not so familiar with the range of bird species. The choice of an appropriate water bird would also be another useful indicator as growers are more likely to notice these as they drive around their farms and irrigation infrastructure.

Cotton crops attract a large number of invertebrates, including benign, pest and beneficial insect/spider and related species. The advantage of using these species as indicators is that insect scouting has been part of the culture of cotton agronomy and many farms will have historical record. The difficulty of using them as biodiversity indicators include the significant time collecting species and challenges with species identification of those species not normally associated with cotton agronomy.

Cotton farms generally occupy less than five percent of the land area in catchments; on cotton properties usually twenty to thirty percent of the land is not used for cotton production so there is considerable opportunity to conserve and enhance biodiversity. Thus, the extent and quality of native vegetation is one practical indicator of biodiversity. It could also become an important component of any carbon emissions trading scheme. Land clearing of remnant vegetation can have an impact on the sustainability of a farm or region; whilst it is now not a common practice on cotton farms, it was 20 years ago when regions were being developed. An alternative indicator of native vegetation stewardship could be breaches related to land clearing restrictions and regulations.

Most (at least 70%) cotton farms have river or creek frontage. The status of the riparian land is an important indicator for the broader catchment sustainability. The crucial factor for a healthy riparian area is the vegetation, which should be managed for diversity and structure, and its width.

Insects, weeds, pesticide use and resistance

Weeds present a sustainability risk to growers as they can make it uneconomic to grow crops or they pose an environmental risk to the broader catchment. Weed densities have fallen over the last 10–15 years. Some of the most troublesome weeds included cow vine, bladder ketmia, noogoora burr, nutgrass, barnyard grass, yellow vine, wild gooseberry, ryncho, and sesbania. Lippia (*Phyla canescens*) is becoming a major weed of floodplains in the Murray Darling Basin and can be found on many cotton farms, but its presence is not related to cotton production.

There has been widespread adoption (about 80% of crop area) of Round Up Ready® transgenic cotton varieties in Australia. This is reducing the use of pre emergence herbicides to those with greater reliance on post emergence application. Herbicide use peaked in 2000–01 and has declined for several years as a result of some new herbicide products and a more integrated weed management approach. Since 2004–05 there has been a dramatic increase in the total use of Roundup® (glyphosate) herbicide. However, the use of some environmentally problematic herbicides such as trifluralin (Treflan®), and Diuron® and Cotogard® (fluometuron, prometryn) has dropped significantly.

The greatest benefit of Roundup Ready® cotton has been the ability to grow crops where there are excessive weeds, especially nutgrass and it has led to less manual chipping, less inter row cultivation and less use of residual herbicides. It is causing a

further species shift in weeds to those more tolerant of glyphosate. For example, a weed that is having increasing impact is fleabane (*Conza bonariensis*). Another is sow thistle (*Sonchus oleraceus*). The development of resistance to herbicides by weeds is a sustainability risk and needs to be monitored.

Insect management has traditionally been the major problem and cost of growing cotton in Australia and around the world. The major change in insect management over the last decade has been the introduction of transgenic cotton varieties.

Transgenic cotton was first grown commercially in Australia in 1996–97 with release of a *Bacillus thuringiensis* (Bt) cotton known commercially as Bollgard®. Since the removal of the planting area cap there has been a rapid adoption of transgenic Bt varieties, which is now used on 90 % (2007–08) of the planted area.

Growers have adopted Bollgard® varieties because of perceived economic and environmental benefits, as well as lifestyle benefits such as worker and family safety benefits. Over the four seasons 2002–03 to 2005–06, average insecticide usage was 82% less on Bollgard® crops than on conventional cotton crops. Bollgard® crops currently receive less than one spray per hectare compared with 7–11 sprays on conventional crops (Pyke 2007).

Insecticide resistance is a major sustainability risk for the cotton industry. The management of insect resistance to transgenic cotton traits is perhaps the greatest potential immediate sustainability risk to the Australian cotton industry. Since the advent of Bollgard® cotton varieties, resistance to many conventional insecticides has declined. There have been no reports of field failures of Bollgard II® varieties due to resistance; however, the data from 2007–08 show an increase in the frequency of *Cry2Ab* resistance alleles in *Helicoverpa punctigera* since the introduction of Bollgard II®. The cotton industry has increased its resistance monitoring in 2008–09.

In the long term the cotton industry will need to adapt to climate change. Whilst the literature strongly agrees the climate will be warmer, there is considerable uncertainty on the rainfall trends. The major risk is that with warmer temperatures, higher evapotranspiration levels and similar rainfall that water availability for irrigation will be less. Cotton Australia needs to formulate a policy related to climate change. Cotton Australia could also strengthen its action plan in relation to maintenance or enhancement of biodiversity.

5 SOCIAL INDICATORS RELATED TO THE AUSTRALIAN COTTON INDUSTRY

A number of commentators concerning triple bottom line sustainability reporting have observed that the social aspects of sustainability reporting have proven the most difficult (Chapter 2). This chapter compiles known and disparate sources of social sustainability data in relation to the Australian cotton industry. Following the literature review, discussions with cotton industry leaders and a workshop with cotton industry stakeholders (Chapter 2), some key social sustainability indicators were compiled for the cotton industry. These were summarised in Table 12. They include education levels, demographics, employment, health, community attitudes, social capital, research and development and compliance with the law. This chapter attempts to find data sets for these indicators.

EDUCATION

Education can be used as a measure of the human capital of the cotton industry. Educational indicators include qualifications, skills, training and potential knowledge development and innovation capacity of people associated with the cotton industry.

Highest post school qualification

The Australian Bureau of Statistics (ABS) includes data on the highest post school qualification obtained by Australians in its four yearly Census surveys. For this project raw data was obtained from the ABS and processed for the “cotton growing” (ABS Classification 0162) and the “balance of agriculture” (excluding cotton growing) from the 1991, 1996, 2001 and 2006 ABS Census.

Figure 52 shows the highest post school qualification obtained by cotton growers between 1991 and 2006. The major trend over the 15 years is that the number of cotton growers with a bachelor degree has risen 8.4% from 13.5% to 21.9% between 1991 and 2006. Post graduate degree qualifications of cotton growers have risen slightly from 0.5% to 1.6% and graduate diploma and graduate certificate have fallen from 1.4 to 0.8%. The majority of cotton growers highest post school qualification is an advanced diploma (2006 – 19.8%) or certificate level (47.5%) qualification.

Figure 53 shows the highest post school qualification obtained by the balance of agriculture (excluding service industries) between 1996 and 2006. The major trends are similar to those for cotton growers with those with a Bachelor degree rising from 11.5% to 16% between 1996 and 2006. Post graduate degree qualifications have risen slightly to 1.9% in 2006. The number of people with the highest post school qualification at graduate

diploma and graduate certificate (2%), Advanced Diploma (18%) and Certificate level (47%) has remained constant. There is currently the first generational succession change between fathers and sons taking place in the cotton industry. It is expected that cotton grower’s graduate qualifications will trend upwards.

The qualification for people classified as cotton ginners can also be obtained from the ABS Census. In 2006, 15% of people classified as cotton ginners had a bachelor degree or higher.

Figure 52 Highest post school qualification for ABS cotton growing classification (0162) 1991–2006

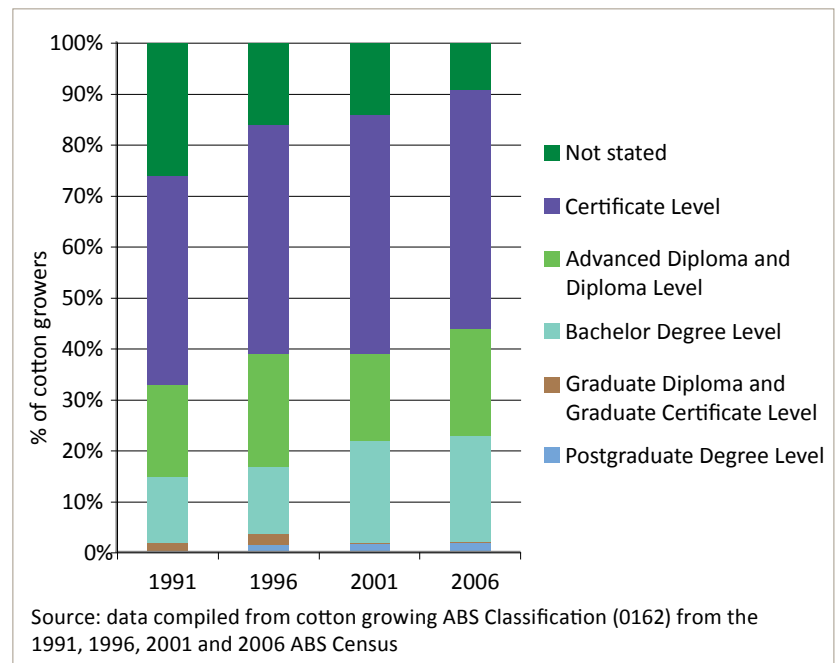
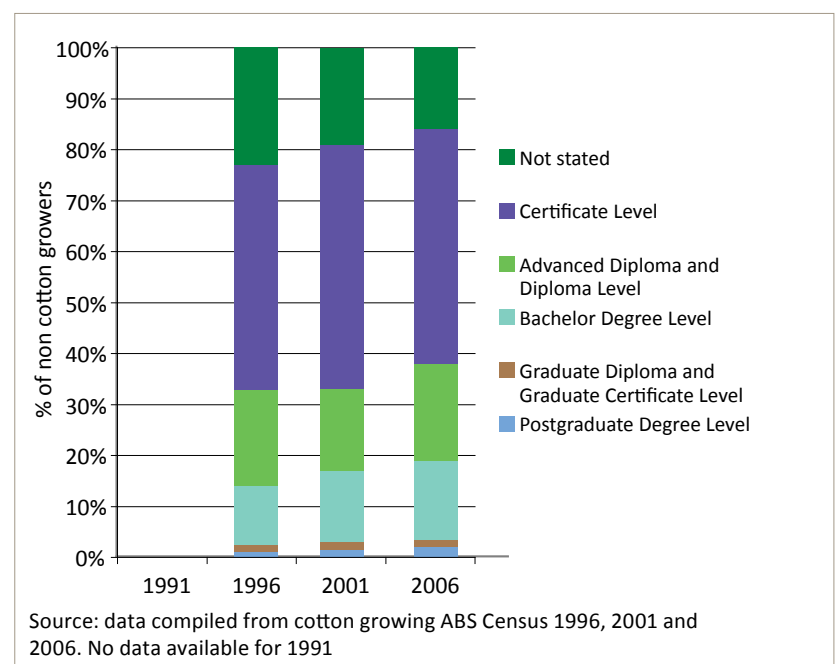


Figure 53 Highest post school qualification for the balance of agriculture, excluding ABS cotton growing classification (0162) 1991–2006



University level cotton education participation

The University of New England (UNE) and the Cotton Cooperative Research Centres have offered a Graduate Certificate and Certificate in Rural Science (Cotton Production) since 1992.

This “cotton course” is the only cotton specific university level course in Australia. Since the course inception, 132 people have completed the course at Graduate Certificate Level, while 69 people have completed it as an undergraduate certificate. Figure 54 shows the distribution of the 201 graduates of the course between 1996 & 2007. The decline in numbers between 2004–2007 is due to the drought.

Figure 55 shows the occupations of the UNE cotton course graduates from 2002–2007. The majority have been agronomists (55%) and cotton growers (17%). This indicates that people that have completed the course are applying their new knowledge directly in the cotton industry. These trends are consistent with earlier data on the occupations of the cotton course graduates that are reported by Stanley *et al* (2003).

Since 1999, 359 undergraduate students at UNE, The University of Sydney and The University of Queensland have completed a unit of applied cotton production as part of their Bachelor degrees in Rural Science/Agriculture Source: Dr John Stanley, UNE Nov 2007, pers. comm.). This means undergraduates are

Figure 54 Number of cotton industry personnel graduating from the UNE / Cotton CRC Cotton Course

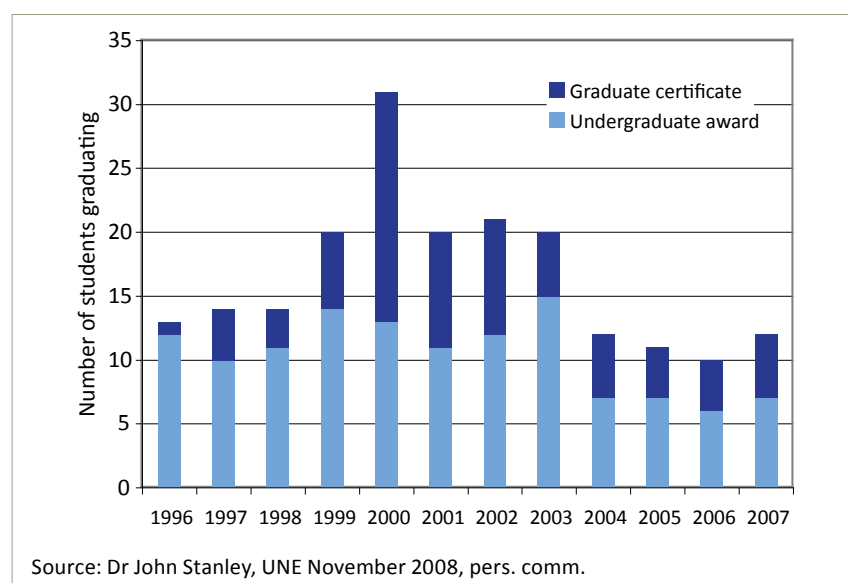
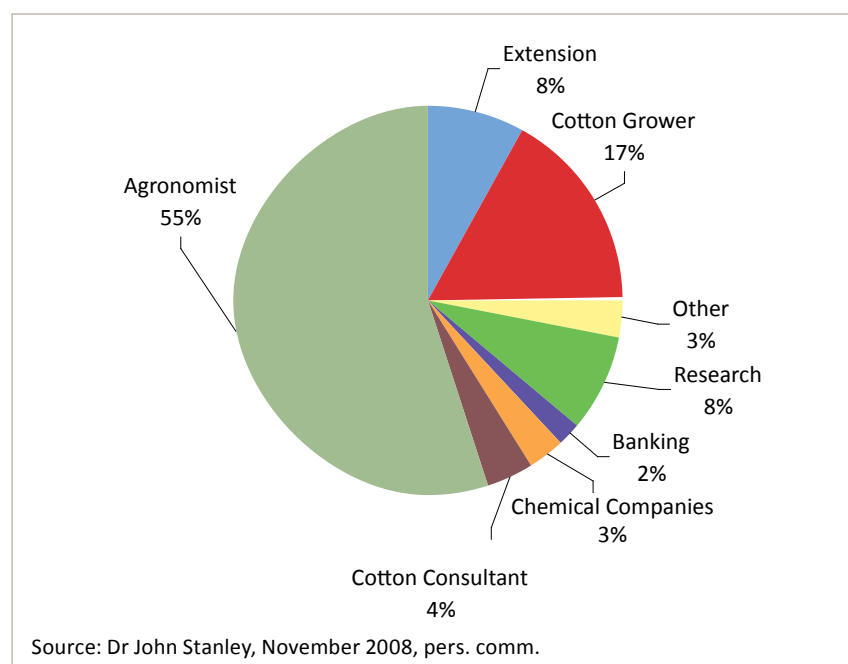


Figure 55 Occupations of graduates of the UNE / Cotton CRC cotton course 2002–2007



learning from an entire semester's unit (150 hours of work) related to cotton production compared to a one hour lecture they would otherwise receive as part of a general pasture and crop agronomy unit. The outcome is that they are better prepared for employment in the cotton industry.

Qualifications of Crop Consultants Australia organisation membership

Most agronomists active in the cotton industry are members of Crop Consultants Australia Incorporated (formerly Cotton Consultants Australia Incorporated). The Crop Consultants Australia membership book 2007 lists every member and their formal qualifications. Their qualifications have been summarised in Table 26, which shows the majority (64%) of their membership have a Bachelor degree or higher while 10 % have no formal qualifications. The high number (20%) of consultants with a Graduate Certificate or Masters higher degree would be mostly those who have completed the UNE cotton course.

Vocational training in the cotton industry

Measures of training in the cotton industry capture the willingness of people to improve their human capital and skill levels. The problem with tracking training data over time is that the short courses come and go as topics become a priority for industry. The proportion of people who have completed training in the last two years may be a better indicator. These data are also difficult to capture because there are so many courses and training providers. By way of example, there are several training initiatives underway in the industry. These include:

- the integrated pest management short course run by the Australian Cotton CRC. A total of 221 people undertook the course between 2001 and 2005 of which 146 achieved the statement of attainment Source: Mark Hickman, Cotton CRC, pers. comm.);
- the 'Cotton Field to Fabric' course focuses on the impact of fibre quality on textile quality and processing performance. A total of 170 people have attended the course since it was first held in August 2005 Source: Rene van de Sluijs, CSIRO, pers. comm.);
- the cotton industry skills development pilot project was an initiative of Cotton Australia with funding support from the Australian Government Department of Education, Science and Training under the National Skills Shortages Strategy. It conducted a series of programs which 109 people had completed in 2007 Source: Neil Jacobson, Cotton Australia, pers. comm.);
- the industry has established a formal vocational and education and training qualification for people to apply for when they have successfully implemented and achieved the industry BMP accreditation status for their farm. Successful participants in the program receive both the industry award and the national qualification (Diploma of Agriculture – Specialising in Cotton Production) from the registered training organisation. This program was released to industry in March 2008, and at August 2008 15 people had commenced the program. The process is described by Hickman (2008);

- A cotton and grains irrigation management workshop series first commenced in May 2007. As of June 2008, 21 workshops have been delivered by the Cotton CRC Water Team and 185 participants have been recorded, which is about 20% of the industry Source: Graham Harris, Cotton CRC, pers. comm.) and
- the CRDC 2007–08 annual report states over the past five years 80% of growers had attended spray application courses and 60% had attended OH&S training (CRDC 2008).

EMPLOYMENT

Employment indicators show the value of the workplace and cotton industry to the community. For this project, data was obtained from the ABS and processed for cotton growing (classification 0162) and the balance of agriculture (minus cotton growing) from the 1991, 1996, 2001 and 2006 ABS Census.

Employment levels

The specific number of people employed by the cotton industry is not clear. The number of people employed by the cotton industry in a non drought year is 10,000 people (Cotton Australia 2008). Cotton production is concentrated in specific regions and is one of the leading employers in most of the places where it is grown. It is a high input annual crop for products and services and therefore generates many permanent and casual jobs and has traditionally provided some of the best salary packages in agriculture. Cotton is also a knowledge intensive industry so there are a high number of service businesses in cotton regions. Employment includes on-farm jobs such as irrigating and machinery operation, fertilizer and chemical sales, aerial and ground spraying services, machinery and spare parts sales and service, engineering services, transport companies, oil seed crushers, cotton gins, agronomists and scientists.

In the 2005–06 grower survey, under full water conditions, WRI (2007a) found the number of employees per farm was 8.4, of which 4.8 were full time, 1.0 part time and 3.2 were casual. Newnham (2006) reports for the 10 years between 1997 and 2006 the number of hectares per permanent employees has ranged from 132.82 to 185.44 with no obvious trend.

Regional multipliers have been used in the past to measure the direct and indirect effects of cotton. A recent study by Powell and Chalmers (2009) calculated gross output, value added output, household income and employment for five cotton regions.

Table 26 Qualifications of the Crop Consultants Australia 2007 Membership

QUALIFICATION	NUMBER OF MEMBERS
PhD	2
Bachelor + Master	7
Bachelor + Graduate Certificate/Diploma	37
Bachelor	92
Diploma	24
Associate Diploma	21
Certificate	13
None	21
Source: data compiled from CCA membership book 2007	

The drought has reduced employment in the cotton industry. For example, permanent staff working in businesses in Wee Waa fell 31% between 2001 and 2004 (Roth and Drew 2004) and 60% between 2004 and 2007 (Jones *et al* 2007). The mining and energy boom is also attracting people away from agricultural employment due to higher salaries, greater security, or merely the opportunity of employment. There are a number of farmers from South Africa and Zimbabwe who have moved to Australia to work on farms.

Changes in technology have also influenced employment levels. For example, Bollgard® transgenic cotton requires less spraying and crop checking compared to conventional varieties. The other major trend as a result of Roundup Ready® transgenic cotton has been the decrease in the amount of cotton chipping for weed control. This has resulted in less casual employment for itinerant, student and indigenous workers. Another technology impact on employment is changing irrigation systems from surface irrigation to drip or overhead systems usually require less labour for irrigating.

The next technology to significantly impact employment levels on cotton farms will be the new cotton pickers that produce their own cotton modules like a round hay bale. These are being trialed during 2009 and orders have been placed for the 2010 cotton harvest.

Income per week

Income per week data from the 2006 ABS Census is shown in Figure 56 for cotton growers and Figure 57 for other farmers not growing cotton. The data shows that 33% of cotton growers, while only 15% of other farmers earned over \$1000 per week. The proportion of cotton growers in lower income brackets is also less, with 32% of cotton growers earning less than \$600/week, whilst 60% of other farmers are earning less than \$600/week.

Hours worked per week

The hours worked per week data from the 2006 ABS Census is shown in Figure 58 for cotton growers and Figure 59 for other farmers. As expected, farmers work long hours with most of them working more than 49 hours / week. The data shows that 54% of cotton growers and 43% of other farmers were working more than 49 hours per week. The data shows that 78% of cotton growers, and 67% of other farmers were working more than 40 hours per week.

This difference between cotton growers working slightly more than other farmers per week may be due to the nature of ir-

rigation farming and the need to irrigate at night, as well as completing spray applications at night.

Figure 60 shows the percentage of cotton growers working more than 40 hours per week between 1991 and 2006. It is clear that over 75% of cotton growers have been working more than 40 hours per week. It is difficult to know if there has been a decline in the proportion of cotton farmers working more than 40 hours/week between 1991 to 1996 or if this is just survey variation. This could be possible as a result of greater mechanization, automation, less spraying, drought, transgenic varieties and general change in work / lifestyle balance by the next generation of younger farmers.

The effects of the extended drought on employment in the cotton industry is well illustrated by the results of a survey conducted in 2004 (Roth and Drew 2004). This is outlined as a case study in the next section.

Figure 56 Average weekly earnings of cotton growers

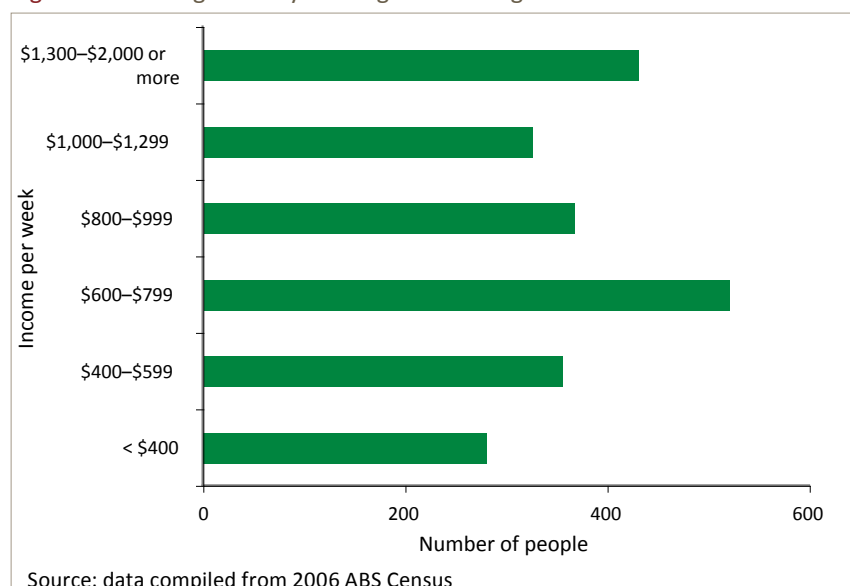
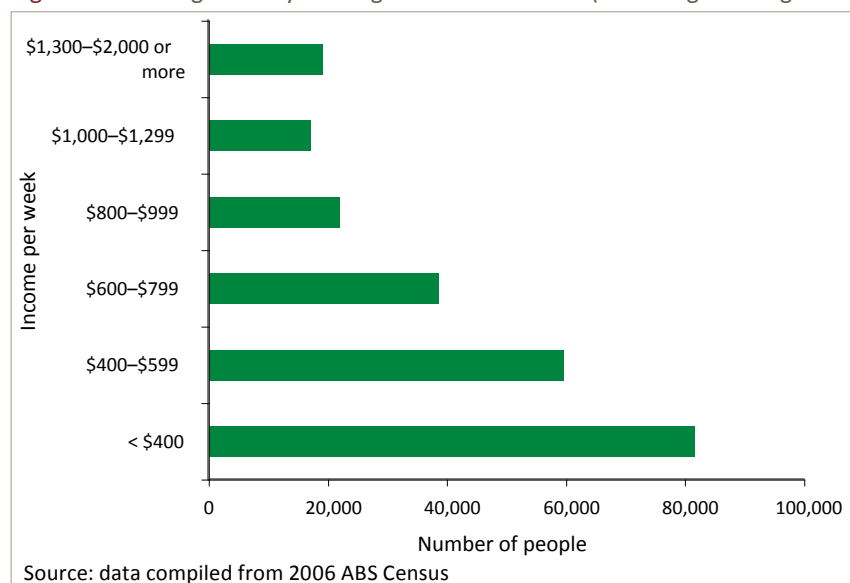


Figure 57 Average weekly earnings for other farmers (excluding cotton growers)



The Impact of Drought – A pilot study on Wee Waa

Guy Roth and Tim Drew

Australian Cotton Cooperative Research Centre



The extended drought in the north west NSW cotton town of Wee Waa had impacts in important areas such as employment – particularly in trade and labouring positions – which affected workforce retention in the region and local school enrolments

The purpose of this 2004 pilot study was to quantify the impact of the drought on a cotton community. 33 questionnaires were distributed via a door-drop to businesses in Wee Waa during the drought. 19 responses were received.

- The survey found that the current gross turnover of the combined businesses was \$110 million, which had fallen by 47% from 2001 levels of \$207 million.
- Most respondents thought that drought had a 50% or greater impact on their subsequent business decisions to restructure, while technology developments such as the internet and transgenic cotton varieties, which have reduced spraying and chipping needs had impacted on some businesses.
- Permanent staff numbers have fallen to 69% of the 2001 figures.
- Casual employment rate is down to 52% of that at 2001.
- Of the professional positions, it could be argued that businesses have maintained junior staff in preference to retaining more senior positions as it is presumed that these would have been on higher rates of remuneration. Trades and labouring positions seem to have borne the major brunt of the reductions as these also may be seen as readily replaced or contracted back when required.
- Of the terminated employees 33 remained in the town; 30 left the region and 30 are unaccounted for.

- Eleven of the 19 respondents (53%) indicated they would return to their pre-drought staffing levels. One indicated the question was N/A (Not Applicable). One respondent indicated that the business would only replace 2 of 4 (50%) specialist positions. Two respondents indicated they would return to 65% and 85% levels respectively. One respondent qualified this strategy by the following reasoning: “due to permanent loss of qualified staff and trade persons leaving town”. One respondent indicate that the business would “possibly not” return to 2001 level of staffing, whilst three (16%) other respondents indicated a definite “No” to the question.
- Wee Waa combined Primary School numbers have declined by a total of 57 students (15.12%) over the period since 2001.

In 2007, the Cotton Catchment Communities CRC (Cotton CRC) analysed demographic data figures for the town of Wee Waa (New South Wales); traditionally a cotton and wheat economy.

The study revealed some significant shifts in labour and management skills from this regional community. Permanent staff numbers fell 60 % between 2004 and 2007. Casual labour fell 40% in the same period. Of the terminated employees, two thirds left the region and the remaining one third obtain another form of local employment or were classed as an unknown occupation (Spanswick *et al.* 2007).

HEALTH

Agriculture is rated as one of the most dangerous occupations in Australia and historically there have been a number of deaths and injuries each year. Other health issues include pesticide exposure and long term exposure to the sun. Evidence of a healthy and safe industry and workplace is a component of a sustainable industry. The Safework Australia website contains up to date trends for the agricultural sector in general (www.safeworkaustralia.gov.au).

Deaths, accidents and injuries

High rates of serious injury and deaths on Australian farms are of concern to agricultural industry agencies, farmers and governments (Fragar and Thomas 2005). Between 1999 and 2002 there were 825 farm manager or agricultural worker injury related deaths occurred on Australian farms, which is about 200 deaths per annum (Fragar and Thomas 2005). Their report provides details on the types of accidents, but does not provide figures specifically related to cotton production. Personal observation indicates that deaths in the cotton industry in the last three years are very low and would generally be less than 2 per year and they usually are associated with vehicles or cotton ginning.

As opposed to deaths, accidents are more common. Table 27 shows accident types within each work production phase of cotton (Franklin *et al* 2001). On cotton farms most accidents are associated with machinery operation (28%), while ginning accidents are also high at 25%. The most

Figure 58 Hours worked per week by cotton growers

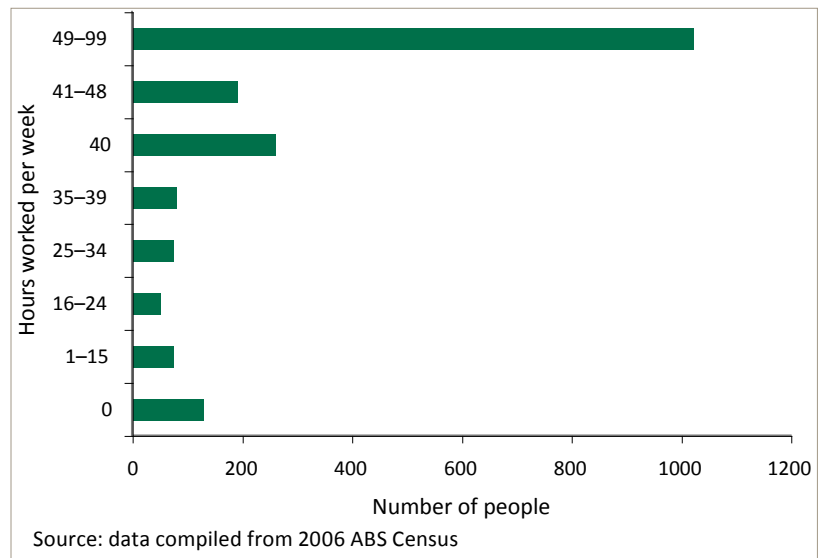


Figure 59 Hours worked per week by farmers excluding cotton growers

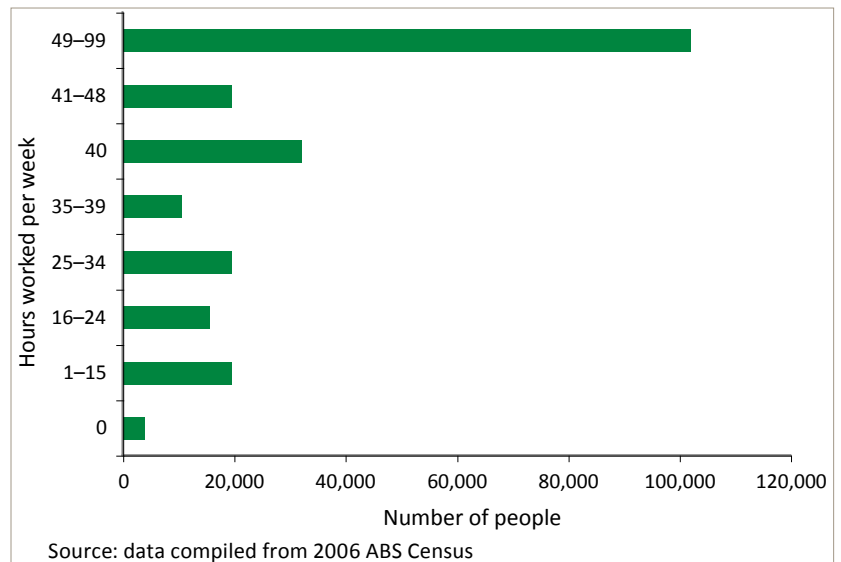
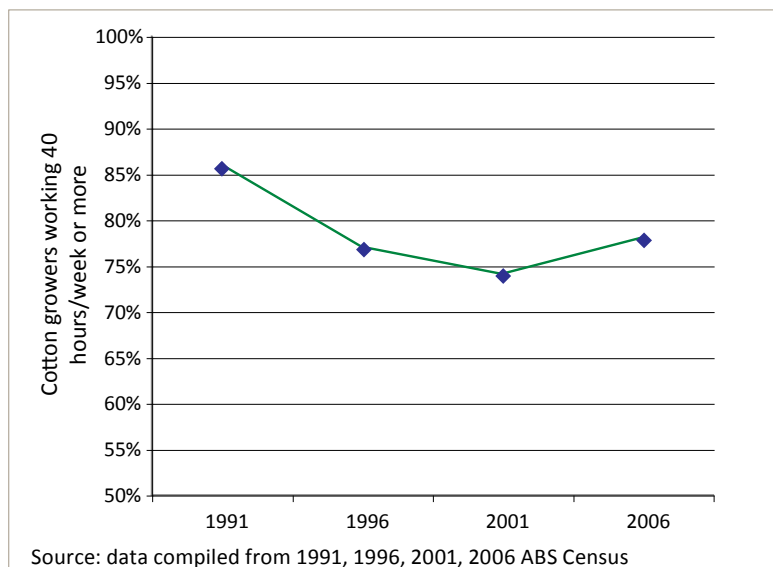


Figure 60 Cotton growers working 40 hours/ week between 1991–2006



common agent of injury was the workshop, mobile plants, hand tools, and fixed plant equipment.

The Queensland workers' compensation information July 1992 – June 1999 for cotton production noted 131 compensation injuries of which over half (63.4%) were aged less than 35 years. Between 1992 and 1999 there was no apparent trend in the occurrence of the claims (reported in Franklin *et al* 2001). Fragar and Temperley (2008) reported workers' compensation claims for the cotton industry, for the years 1997 to 2005-06 the number of claims (excluding journey claims) has varied each year. It would be expected that the number of claims would be directly related to amount of cotton being produced in any year, but it is not always the case in Figure 61.

The Cotton Research and Development Corporation Strategic Plan 2003–2008 included a strategy to promote safe, healthy workplaces through the adoption of appropriate occupational health and safety work practices (CRDC 2003). CRDC co-funded the Farm Health and Safety Joint Venture with other Rural

Research and Development Corporations to reduce deaths and accident levels in the cotton industry.

The cotton industry also collaborated with FarmSafe Australia in order to help facilitate a reduction in deaths and injuries. The Managing Farm Safety Program includes manuals, workshops and videos that provide a systematic approach to safe work practices. The CRDC 2006–07 annual report noted that an evaluation of this program received good feedback, but the evaluation highlighted the difficulty of specifying the number of lives saved or injuries prevented due to the FarmSafe program (CRDC 2007).

The cotton industry has trialed a Sustainable Farm Families Program that addresses personal health and safety issues important to farming families. Workshops in Wee Waa and Dalby received very positive evaluation from participants (CRDC 2007). Average baseline characteristics of participants were collected. Thus, when the cotton project is completed comparisons may be able to be monitored into the future.

The University of Sydney Centre for Agricultural Health and Safety is due to report some updated figures on occupational health and safety in the cotton industry by the end of March 2009 (Helen Dugdale, pers comm., Nov 2008).

Pesticides and human health

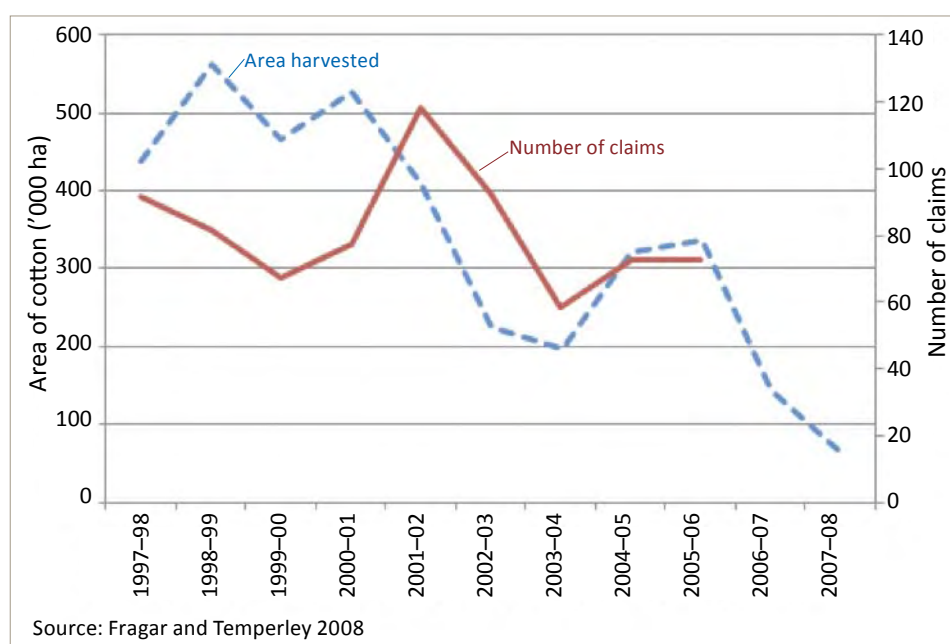
Pesticides are commonly used on cotton farms and pose a significant potential human health risk. Data which describes the full, or even partial, extent of human health effects from exposure to pesticides is difficult to source due to the potential long latency periods for chronic illness, the difficulty in diagnosis, the non-specific nature of pesticide health effects and the lack of effective monitoring systems (Fragar *et al* 2005).

Table 27 Accidents types in the Australian cotton industry

ACTIVITY CAUSING ACCIDENT	NUMBER OF ACCIDENTS	%
Ground Preparation	19	5.9
Planting	15	4.6
Plant Growth	37	11.4
Picking and Carting	36	11.1
Machinery and Equipment and Maintenance	92	28.4
Ginning	18	25
Unknown	44	13.6

Source: Franklin *et al* 2001

Figure 61 Workers compensation claims in the cotton industry 1997–2008



There were 81 deaths in Australia caused by the external poisoning of pesticides between 1997 and 2001 (Fragar *et al* 2005). Twenty one of these deaths were associated with agriculture/horticulture and 17 of the 21 deaths were intentional.

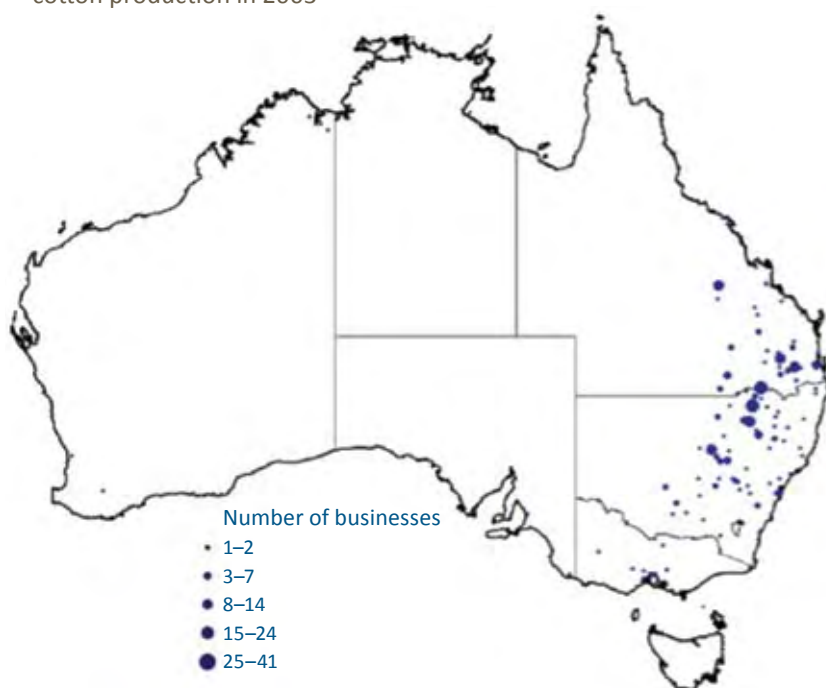
The majority of claims submitted to workers compensation agencies relating to exposure to plant and animal treatment chemicals from 1994–2000 relate to agriculture/forestry/fishing industry group. It was estimated that between 13 to 33 claims relating to plant treatment chemicals were submitted to workers compensation agencies across Australia per annum. They report that while the data are limited, it suggests that workers in the horticultural and fruit growing industries may be at greater risk of pesticide exposure than other agricultural industries (Fragar *et al* 2005).

Strategies in place to reduce pesticide related accidents in the cotton industry include:

the Cotton Best Management Practices Program modules on pesticide application, pesticide storage and integrated pest management. Trends in industry practice related to these modules are reported in Chapter 6.

IPM strategies for crop management that encourage less use of pesticides, use of only authorized pesticides, use of alternatives to pesticides such as biological products and attractants, the use of less toxic chemicals, spray drift workshops and training, and the use of transgenic cotton varieties around homes, workshops and towns.

Figure 62 The demographic distribution of business related to cotton production in 2003



Source: Reeve *et al*. 2003

DEMOGRAPHICS OF THE AUSTRALIAN COTTON INDUSTRY

Grower numbers and distribution

Chapter 3 provides a summary of grower numbers and their geographic distribution.

Figure 62 shows the location of the businesses listed in the Australian Cotton Yearbook (Reeve *et al*. 2003). The map is illustrative of how economic linkages and networks extend not only where cotton is grown, but to other business centres including capital cities. As expected most businesses are located in the major cotton regions, but there are a number in capital and provincial centres. In the long term, changes to this distribution may occur as a result of structural adjustment associated with climate change, water scarcity or infrastructure changes like rail, airports and the internet.

Age of people in the cotton industry

The ABS 2001 Census data indicates the age of people in the cotton industry. Figures 63 and 64 show that cotton farmers are younger than other farmers that do not grow cotton. Fourteen percent (14%) of cotton growers are aged 15–24 years old, 26% are aged 25–34 years old, 27% are aged 35–44 years old, 20% are aged 45–54 years old, 10% are aged 55–64 years old, while 3% are 65 years old or older. Figure 64 shows the age of farmers not involved in cotton production. Ten percent (10%) of other farmers are aged 15–24 years old, 16% are aged 25–34 years old, 22% are aged 35–44 years old, 22% are aged 45–54 years old, 19% are aged 55–64 years old, while 11% are 65 years old or older. The 2006 Census data was not available when the analysis was undertaken. WRI (2008) reported that most (65%) of cotton agronomy consultants were aged between 35 and 49, whilst

14% were younger than 35 and 21 % were aged between 50 and 64 years old.

Gender

The CRDC strategic plan 2003–2008 includes a strategy to foster the development of opportunities for women in the cotton industry (CRDC 2003). There is now greater participation in cotton industry bodies by women. Cotton Australia and CRDC have both had women undertake the role of Chair of the Governing Board and have had 1–2 female Board members in the last five years. Women occupy a number of senior positions in the industry, while at the coal face the cotton industry has many young women in roles such as agronomists and in cotton marketing. Table 28 shows the number of women working in key industry organisations.

The CCA membership in 2007 was 15% female in 2007 Source: data calculated from CCA membership book 2007). This chapter also includes a discussion on Wincott, a women in cotton network (Section 5.6, Table 31).

Aboriginal communities

Within cotton communities a significant proportion of the population are aboriginal people. The Cotton Catchment Communities CRC funded a scoping study on aboriginal participation in the cotton industry and the findings have been published by Cotter *et al* (2006). Table 29 shows the indigenous people make up 19.9% of the population of Moree Plains Council, 9.2% of Narrabri, 15.8% of Narromine, 12% of Warren, and 6% of Dalby compared to the Australian average of 2.3% (Stubbs *et al* 2008). Cotter *et al* (2006) reported that about half of the proportion of the aboriginal populations were less than 19 years old. Cotter *et al* (2006) also concluded that aboriginal people are an under utilised human resource given the increasing lack of skilled labour. The Cotton Catchment Communities CRC has developed programs to enhance employment opportunities. The Aboriginal Employment Service established by the Gwydir Cotton Growers Association has been active in this area for many years.

Social demographic trends for cotton communities

The Cotton Catchment Communities CRC commissioned research to examine social indicators in cotton communities. Snapshots of

Figure 63 The age of cotton growers in 2001 (ABS classification 0162)

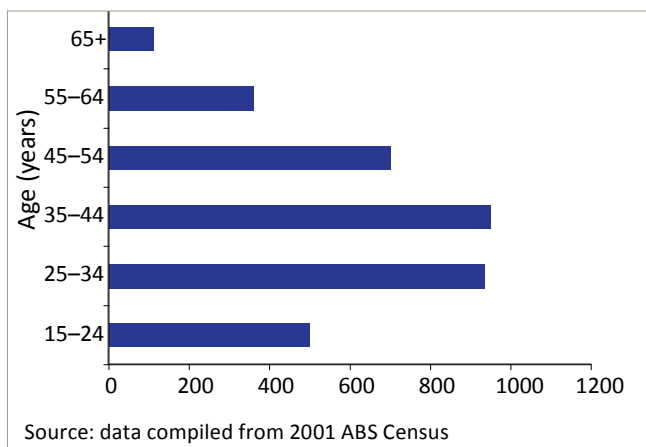
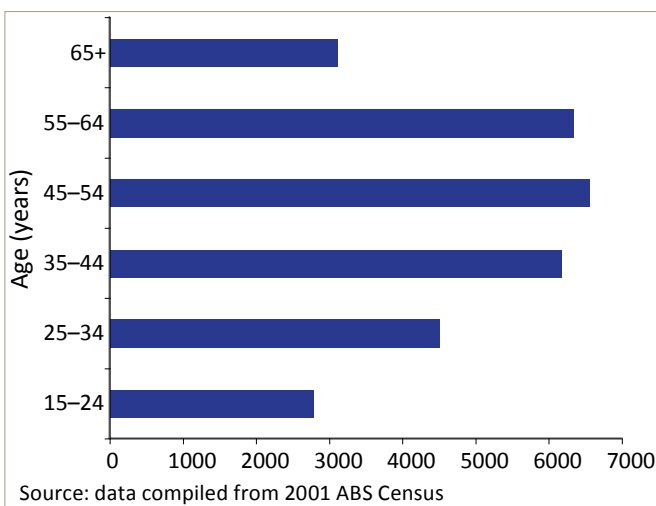


Figure 64 The age of farmers in Australia excluding cotton growers in 2001 (ABS classification 0162)



the findings are shown in Table 29 (Stubbs *et al* 2008). Some key trends include:

- the median household income is less than State averages;
- most areas have experienced depopulation during the period of 2001 to 2006. A large proportion of this decline in population may be attributable to the impact of the drought. Dalby and Wambo experienced an increase in population between 2001 and 2006, which may be attributed to the energy boom. Populations have been declining in most cotton regions and towns since 1991 (Reeve *et al* 2003);
- there is a high proportion of indigenous people;
- the Australian Bureau of Statistics Socio-Economic Index For Areas (SEIFA) index of disadvantage shows that all of the study areas are disadvantaged relative to the national average, again with the NSW areas significantly disadvantaged compared to the Queensland towns;
- higher than state average youth unemployment;
- a number of health indicators were also considered. Of most concern was the high level of premature mortality across the study areas with Warren and Narrabri having the highest rates at around 50% above the NSW average, as well as relatively high crime rates across the study areas; and
- higher than state average of voluntary work.

Other published data highlights the low number of people in the age bracket 20–30 years old in many of the cotton towns (Powell and Chalmers 2009). This could have significant implications on the future populations of some of these towns as this generation has moved elsewhere to follow their interests.

It should be noted that it is not possible to attribute all these trends in Table 29 entirely to the cotton industry and most of them are similar to all western country towns.

COMMUNITY ATTITUDES

Community attitudes are important as they influence the social licence or right to farm cotton. Personal observation during this study has found that most people outside the cotton industry have a negative attitude towards the cotton industry. This observation is confirmed by attitudinal studies in cotton communities and other cities.

Between 1995 and 2000, Cotton Australia commissioned five separate studies that investigated community attitudes towards the Australian cotton industry. They were carried out by professional companies in attitudinal research, namely Stollznow

Table 28 The proportion of female staff in industry organisations (2007–08)

ORGANISATION	FEMALE (%)	TOTAL NUMBER
Cotton Australia staff	50%	8
CRDC staff	50%	10
Cotton CRC staff	80%	12

Source: Cotton Australia annual report 2007–08, CRDC Annual report 2007–08, Cotton CRC annual report 2007–08

Research and Roy Morgan Research. The issues raised in these studies on the cotton industry between 1995–2000 were:

- community health: harmful chemicals, chemical smells, aircraft noise and spraying, beef cattle contamination by Helix and endosulfan, and soil contamination;
- pesticides: excessive use, spray drift, insecticide, herbicide and defoliant use;
- river water: chemicals in the water and run off, high water use, salinity;
- groundwater: excessive use drying up stock bores, chemicals;
- soil: exploiting soils, chemicals and residues;
- land clearing and laser levelling;
- cotton growers: greedy, arrogant, irresponsible and only in it for the short term;
- cotton industry: was as all powerful, secretive and dishonest;

- cotton rated consistently low in surveyed attributes compared with other industries; and
- Moree and Gunnedah were noted as towns where there was most community negative orientation towards the cotton industry.
(Source: Summarised from Stollenznow 1995a, Stollenznow 1995b, Stollenznow 1997, Stollenznow 1998, Roy Morgan Research 2000).

In 2003, these issues were still of concern as shown by the second environmental audit of the cotton industry conducted by GHD (2003). The main concerns of the community were water allocations and pesticide usage. Other concerns were groundwater depletion, wildlife corridors, salinity, spray drift and water quality.

In 2004 Cotton Australia and CRDC commissioned further attitudinal research into the cotton industry by Roy Morgan Research (2004). This study included major cotton towns, some large

Table 29 Key social indicator findings of shires where cotton is grown

SOCIO-ECONOMIC INDICATOR	MOREE PLAINS	NARRABRI	NARROMINE	WARREN	DALBY	WAMBO	MILLMERRAN	NSW	QLD	AUS
Median Household Income (\$/week)	\$946	\$792	\$725	\$696	\$940	\$790	\$795	\$1036	\$1033	\$1027
% Population Change (2001 – 2006)	-9.9	-5.5	-3.2	-15.2	+1.3	+1.5	-21.8	+3.4	+10.7	+5.7
% Population - Indigenous 2006	19.4	9.2	15.8	12.1	6.1	2.7	2.7	2.1	3.3	2.3
Median Age	34	37	38	40	34	39	39	37	36	37
SEIFA Disadvantage	928.88	966.82	948.24	959.53	989.52	995.6	976.17	1000.46	991.53	1002.2
Skills Base - % of pop 15+ w/ trade or better qualifications	28.9	29.1	29.6	27.9	28.9	27.6	25.1	40.7	37.6	30.1
Labour Force Participation (15+)	61.8	61.3	59.8	64.1	62	65.3	62.3	58.9	61.8	60.4
Labour Force Participation (65+)	20.4	14.9	17.6	26.6	10.0	28.2	18.6	8.49	8.57	8.42
Youth (15-24yrs) Unemployment Rate	13.2	13.9	15.3	13.8	9.3	4.3	7.3	11.5	8.9	10.2
Premature Mortality Rate	3.28	4.88	3.94	4.64	DNA*	DNA	DNA	2.6	DNA	DNA
Chronic Disease Index (Rate per 1,000)	922.5	950.7	958.7	DNA	996.1	982.7	940.4	885.3	959.1	928.7
Crime Rate (Steal from Dwelling)	571.0	592.7	440.8	672.2	DNA	DNA	DNA	358.8	DNA	DNA
Crime Rate (Total personal crime)	3325.9	1961.6	1905.3	2658.2	DNA	DNA	DNA	1190.2	DNA	DNA
Voluntary work for an organisation	22	25.8	26.3	29.1	22.1	30.2	28.5	17.1	18.3	17.9

Source: ABS (2006) Census of Population and Housing Census, Population Health Information Development Unit (PHIDU) (2005), NSW Bureau of Crime Statistics and Research (BOCSAR) (2007)*. DNA – Data Not Available. SEIFA – Socio-Economic Indexes for Areas. Source: Stubbs *et al* 2008

regional centres nearby the cotton communities but themselves not cotton towns (Dubbo, Toowoomba, Tamworth), Brisbane and Sydney. Community member's responses on the cotton industry in 1998 and 2004 were reported.

In 1998 chemical use was still a major concern, but by 2004 this had reduced significantly in all centres (Figure 65).

Related to chemical use is spray drift, which was also less of a community concern in 2004 than it was in 1998 (Figure 66). Spray drift concerns dropped dramatically in Goondiwindi, and Warren/Narromine. Most concern about spray drift remained

in Emerald and Dalby. These changes can be attributed to the improved practices of growers discussed in Chapter 6 as well as the high adoption rates of transgenic cotton.

There was a reduction between 1998 and 2004 in the concerns related to high water use, especially in Moree and Narrabri (Figure 67). Roy Morgan Research (2004) concluded the regional towns had higher levels of concern relating to water use than chemicals and spray drift because chemical use and spray drift is not close enough to affect them, while taking water from the

Figure 65 A comparison of community concerns in cotton growing regions regarding agricultural chemical use between 1998 and 2004

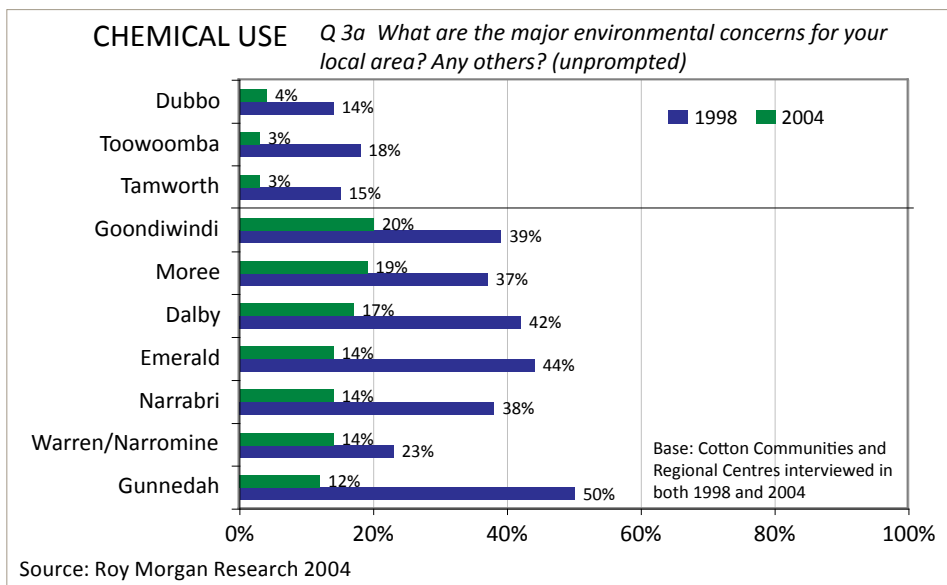
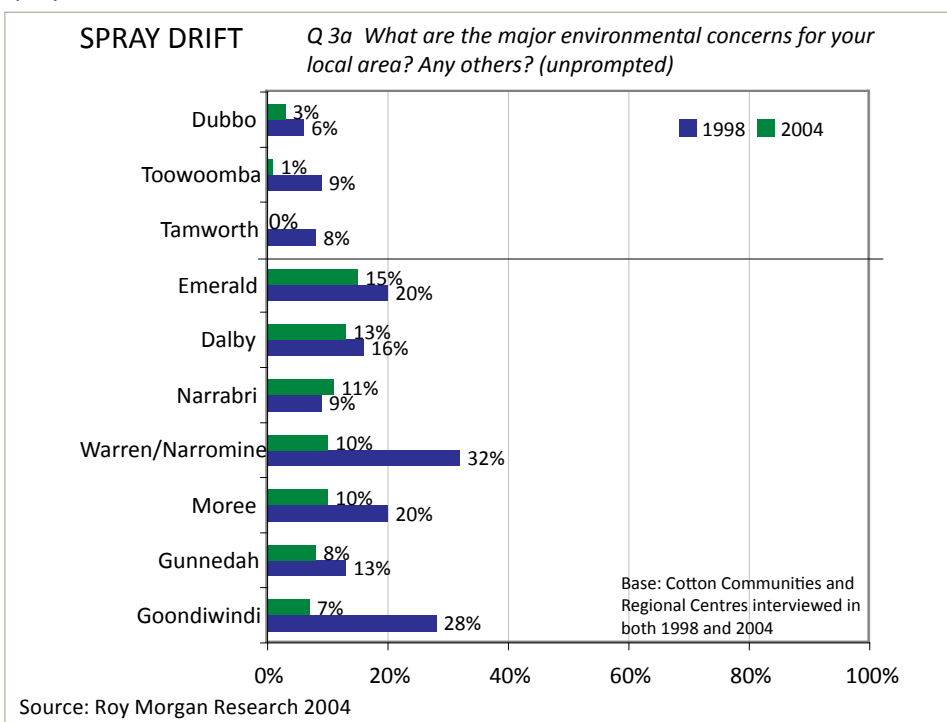


Figure 66 A comparison of community concerns in cotton growing regions regarding spray drift between 1998 and 2004



river system does affect regional centres that rely on the same system.

Figure 68 compares community attitudes on four agricultural industries and how they care for the environment. The cotton industry was viewed as the least effective in caring for the environment. People in Brisbane and Sydney rank all four industries lower compared to other regional towns, and the rice and cotton industries rank the lowest. People in regional centres have a view that tends to be in between those living in the cities and those living in cotton communities.

The study asked all respondents if they had a positive opinion, negative opinion, or no opinion at all in relation to the cotton industry (Figure 69). It found the majority of people living in cotton communities reported a positive opinion (55%) of the cotton industry compared to 37% for people in major regional centres and 27% for city people. In the cities, most people (49%) had no opinion on the cotton industry, while 24% had a negative opinion. These figures directly reflect the level of knowledge of the cotton industry since this has an important influence on opinions (Roy Morgan Research 2004).

Figure 70 ranks the cotton communities in order according to the number of people that had the most positive opinion of the industry. Goondiwindi and Narrabri residents held the highest opinions, whilst Dalby and Hillston were the lowest.

There is also evidence that people in cotton communities have positive feelings about their community (Stubbs *et al* 2008). They surveyed five communities, although the results are based on a very small survey number. My personal observations in Narrabri, where I live, confirm this finding.

One of the most significant changes to cotton industry practices has been the rapid adoption of cotton varieties with genetically modified traits. Stollznaw (1995) surveyed community attitudes at the time of the introduction of the genetically modified cotton. They found that there was some awareness of it, and that the general community

Figure 67 A comparison of community concerns in cotton growing regions regarding high water use between 1998 and 2004

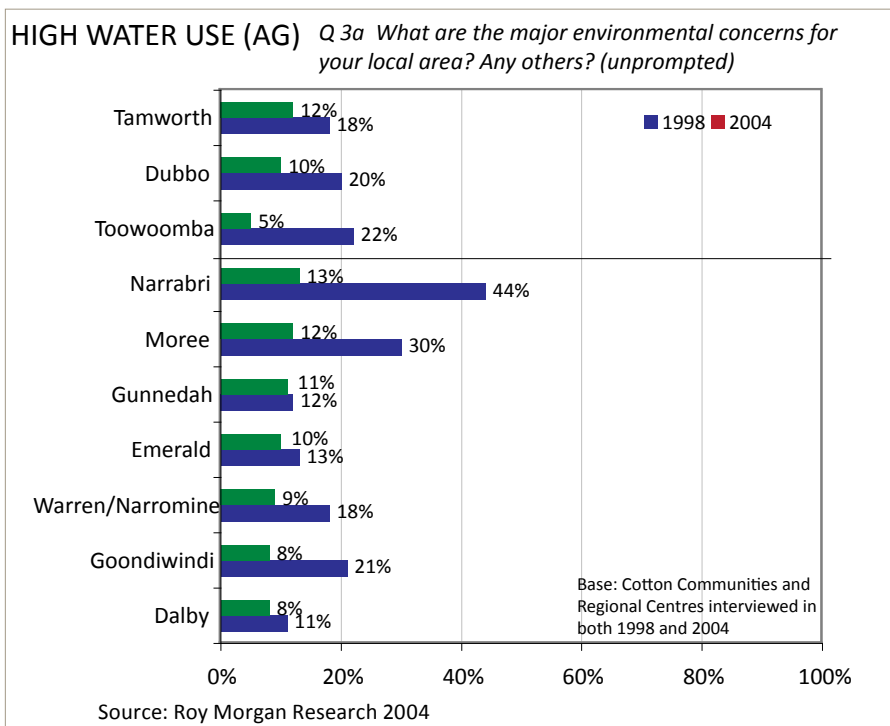


Figure 68 An opinion of the effectiveness of four agricultural industries caring for the environment

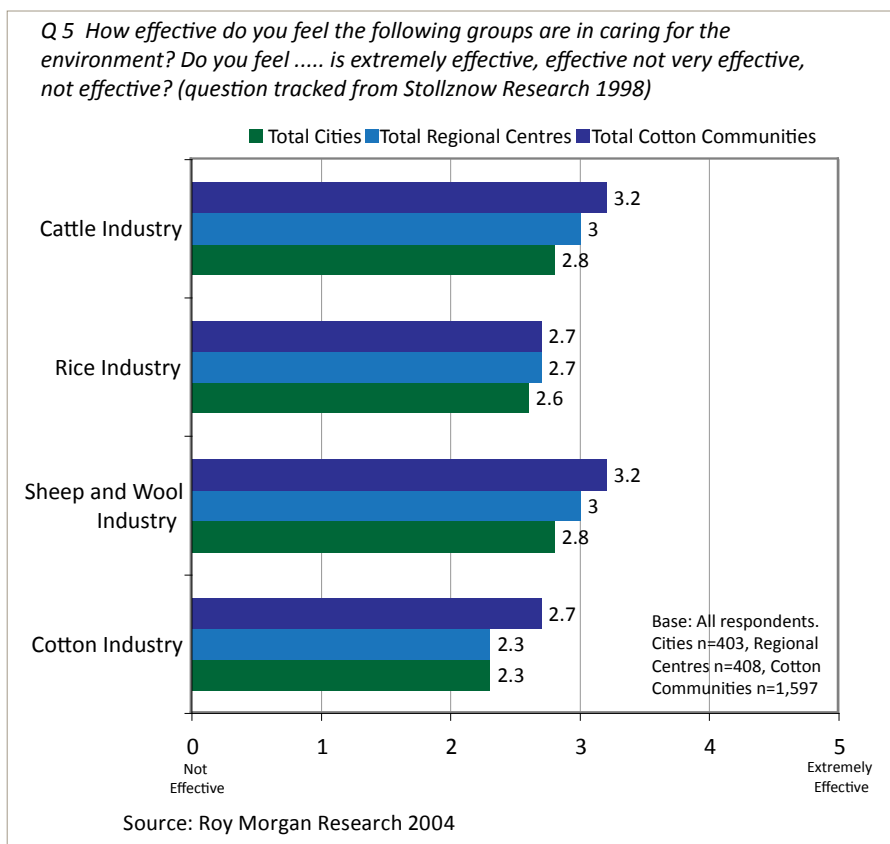


Figure 69 An opinion on the cotton industry

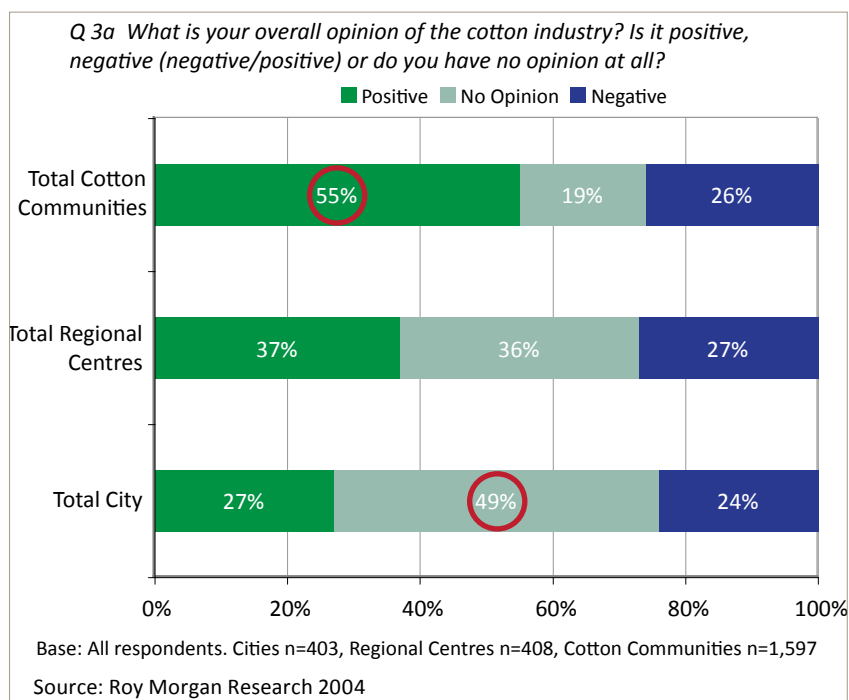
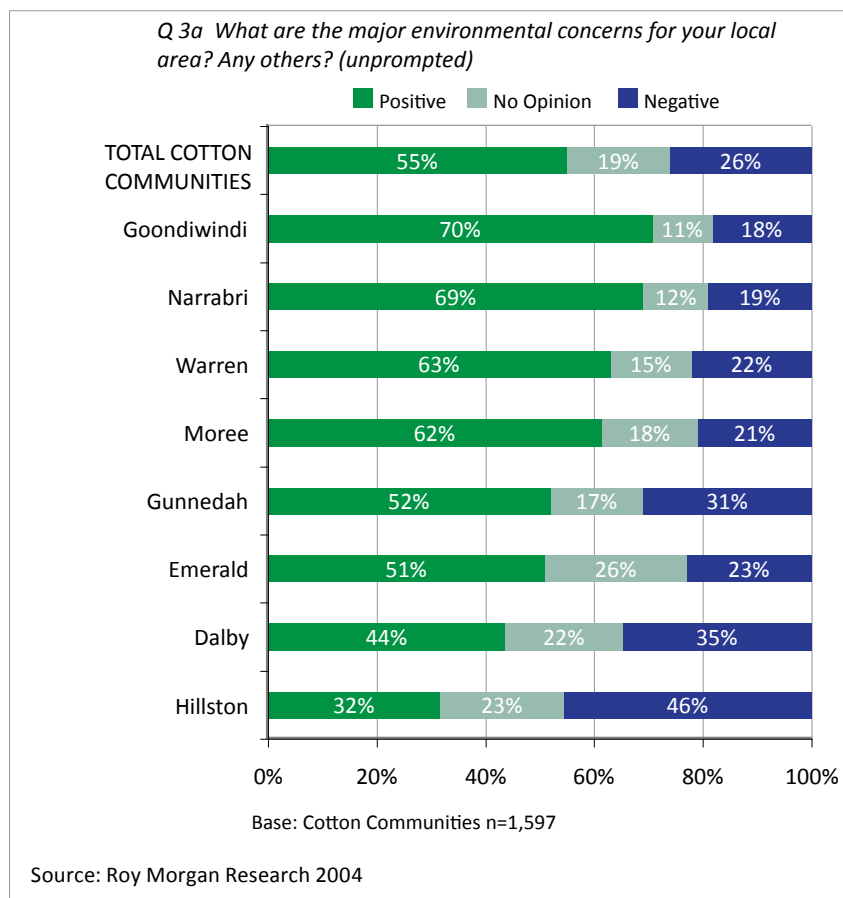


Figure 70 A comparison of cotton growing community opinions on the cotton industry



welcomed it if it would reduce chemical use, however environmentalists opposed its use. Figure 71 compares the views of people in the 2004 Roy Morgan Study on genetic modification. Just under 50% thought it was OK for cotton as a fibre, but most people still had concerns in relation to genetic modification and food crops. The acceptance of transgenic cotton will play a critical role in the future sustainability of the cotton industry. If for some reason transgenic cotton became less accepted by the community and the industry was forced to drop the use of the technology, it is very likely that growers will switch to alternative crops, although some growers will plant conventional varieties.

Attitudes of people within the cotton industry have not been surveyed over time. However, strong support for genetically modified traits has been evident. Evidence for this includes the rapid uptake and investment by growers in the technology. The major concern of growers has been related to pricing policies which differ in Australia to the USA.

SOCIAL CAPITAL

Social capital refers to features of social organisation, such as networks, and cooperation for mutual benefit. Social capital focuses on the capacities of groups of people and their interactions, while human capital focus on the capacity of individuals. Characterising the structure of social capital involves describing the size and density of networks, while the content of social capital includes the degree of trust and prevalence of reciprocity with networks (Johnson *et al* 2005). Researchers have shown statistical associations between high levels of social capital and a range of benefits including democracy, improved physical health, self rated happiness, public safety and enhanced economic performance (Johnson *et al* 2005).

One strong network in the cotton industry is the crop consultants many of whom belong to the Crop Consultants Australia. Their membership figures are shown in Table 30 and generally follow a similar trend to the area of cotton planted. Many of their members are sole traders and value the professional network.

In July 2002, a 'women in cotton' organisation known as Wincott was formed. Wincott membership has grown to 160 members

(Table 31). Wincott has enabled a women's network to develop, and strengthen the linkages or social capital within the industry. It would be interesting to examine if it in turns strengthens linkages with the general community because of the different activities women commonly undertake compared to men.

Another indicator of the social capital of the cotton industry is the delegate numbers at the biannual Australian Cotton Conference. Fourteen conferences have been held and it is one of the largest conferences of any agricultural industry in Australia. Table 32 lists the delegate numbers for the last four conferences. The decline in 2008 was believed to be due to the ongoing drought, however cotton industry leaders were surprised with the continued strong attendance.

The cotton industry has a number of other networks. Each cotton growing region has a Cotton Growers Association. Nationally, the industry is made up of organisations such as Australian Cotton Shippers Association, Cotton Consultants Association (now known as Crop Consultants Australia), Cotton Australia and the Australian Cotton Industry Council.

Another possible indicator of social capital and networks is technology access and the use of the internet. For example, in the

1980s weather forecasts were received by farmers via the radio, in the 1990s by fax, and now they receive them via the Internet. Figure 72 shows the number of internet site hits for the Cotton CRC between 2004 and 2007 and despite a falling crop size and number of industry participants, internet usage is rising. Table 33 shows how the number of growers connected to the internet has changed since 1996. There has been rapid adoption and almost every cotton grower has internet access.

The cotton industry provides a number of scholarships for educational, training and professional development to further enhance its social capital. These include:

- Australian Rural Leadership Program;
- undergraduate scholarships;
- supported leadership courses;
- summer and honours scholarships for university students;
- a schools program;
- cotton industry centre in Narrabri;
- future leaders development program;
- young professionals network; and
- the Cotton Trade Show in Moree.

Figure 71 Community views on genetic modification of food and fibre

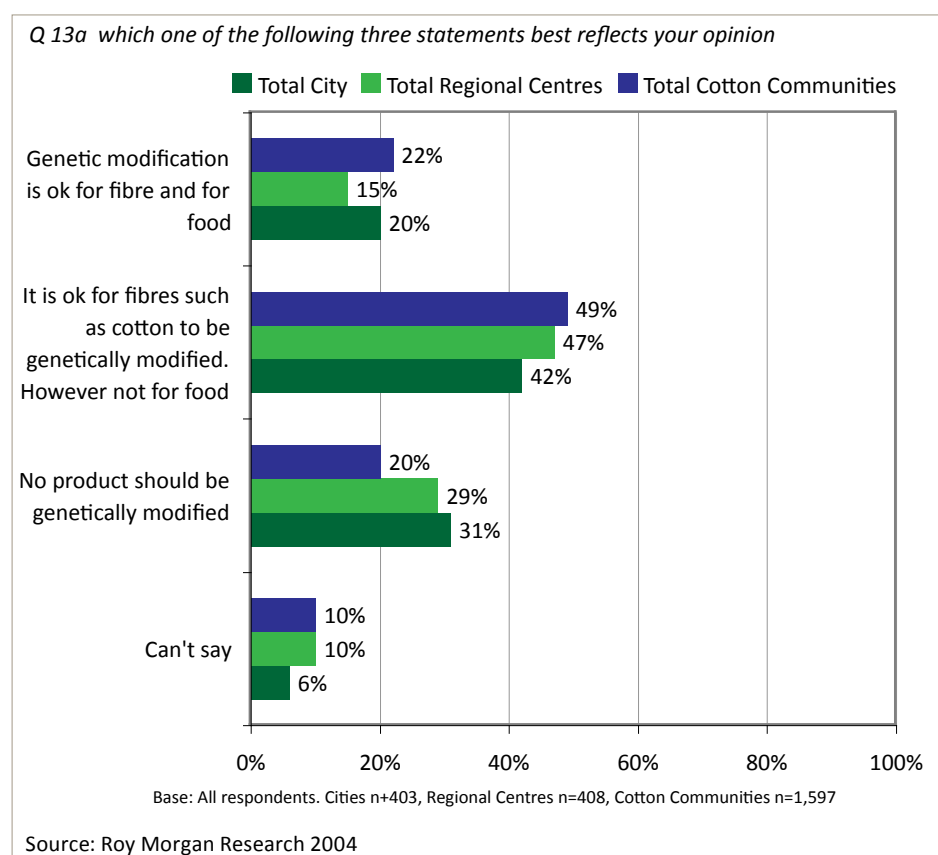


Table 30 Membership numbers of Crop Consultants Australia

YEAR	TOTAL
1996–1997	185
1997–1998	237
1998–1999	268
1999–2000	279
2000–2001	307
2001–2002	337
2002–2003	317
2003–2004	271
2004–2005	265
2005–2006	251
2006–2007	222
2007–2008	185

Source: CCA pers. comm. 2008

Table 31 Membership numbers of Wincott

YEAR	2000	2001	2002	2003	2004	2005	2006	2007
Memberships	50	90	150	80	80	200	200	160

Source: K Schwager, Wincott, pers. comm. 2008

RESEARCH AND DEVELOPMENT

The Australian cotton industry has always invested in research and development. Expenditure levels have generally been around \$11 million per year, although they have been less in recent years due to the drought and reduced production. Cotton growers pay a \$2.25 per bale research and development levy. In low production years less levies are collected, which are matched using complicated formulas by the Australian Government (Table 34). The CRDC does not spend all its income each year. Cash reserves are kept and used during low income years caused by drought to reduce the variation in the research and development expenditure budget.

The cotton industry has also been an active participant in the Australian Government's Cooperative Research Centre program. In 1994 there was the CRC for Sustainable Cotton production, which was followed in 2000 by the Australian Cotton CRC. In 2006, the Cotton Catchment Communities CRC commenced operations and it will operate until 2012.

Post graduate student numbers is one indication of the potential intellectual capital that the industry is prepared to invest in as part of its research and development strategy. The cotton industry has supported many post graduate students undertaking a PhD. CRDC provided 91 postgraduate scholarships between 1990 and 2003 (Roth 2003). Over 95% of these were PhD students with the remainder being research masters students. CRDC was funding 21 post graduate students in 2006–07 (CRDC 2007). The Cotton Catchment Communities CRC has a target of

50 postgraduate students between 2006 and 2012 and these are completed or underway. Previously the Australian Cotton CRC provided 37 postgraduate scholarships between 1999–2005 (ACCRC 2005). This means that 199 Post Graduate scholarship projects have been completed or are underway since 1990, most of which were PhDs (>95%).

The staff numbers at the Australian Cotton Research Institute, Narrabri (Figure 73), also provides an indication of a portion of the research and development investment by many parties in the Australian Cotton Industry. The impact of the droughts is evident in 1991, 1996, 2002 and 2008. A noticeable increase can be seen in the staff numbers around 1993, 1998, 2006 with the establishment of each of the three Cotton CRCs when otherwise staff numbers would have declined significantly due to droughts or the closing down of the CRCs.

The annual reports and internet sites of CRDC and the Cotton CRC provide comprehensive details on the cotton industry's research and development activities.

Table 33 Internet connection of cotton growers

YEAR	1996	2002	2006	2007
	%	%	%	%
Internet connection	26	91	99	99

Source: data compiled from Inglis and Shaw 2000; Christiansen and Price 2002; CCA 2007a; WRI 2007a

Figure 72 Web hits of the Cotton CRC web site 2004–2007

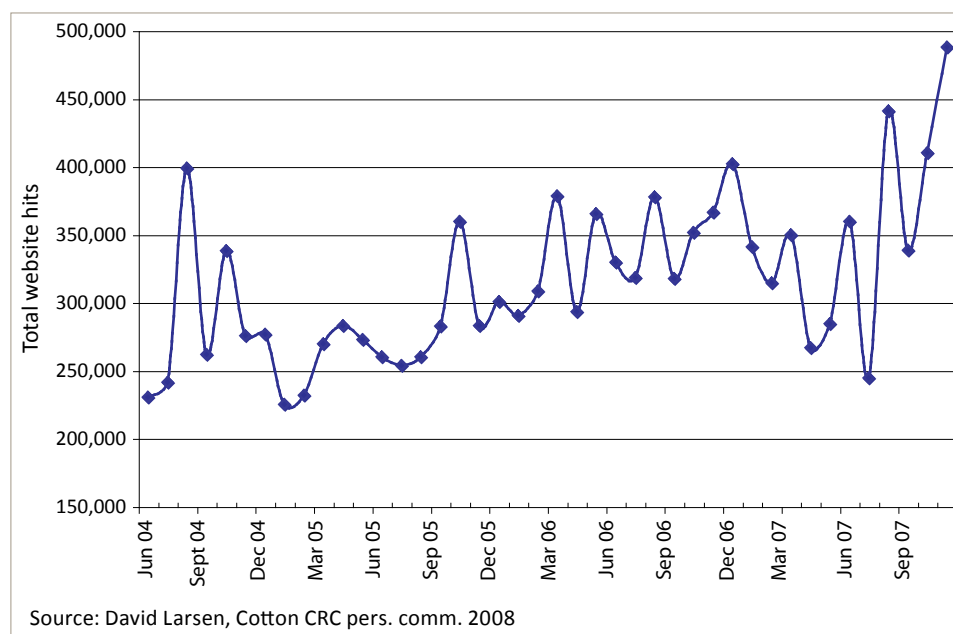


Table 32 Australian Cotton Conference Delegate Numbers

YEAR	2000	2002	2004	2006	2008
Delegate numbers	1413	1392	1478	1302	896

Source: Roth unpublished data

RESPONSIBILITY AND COMPLIANCE WITH THE LAW

The number of breaches of legal statutes is not widely reported by Government agencies, although individual cases usually attract plenty of publicity at the time of prosecution.

Number of complaints to the EPA.

The NSW Environment Protection Authority was contacted and provided some data on the cotton related complaints in NSW between 1/1/98 until 12/12/07. The total number of cotton related complaints was 229 and Figure 74 shows the breakdown per year Source: NSW EPA pers comm. 1/12/2007). There has been a dramatic drop in the number of complaints since 2001, down to 3 per year for 2006 and 2007. This can be attributed to a number of linked factors including the implementation of the Cotton BMP program, greater use of transgenic cotton varieties and a reduction in the crop area due to the drought. Less complaints leads to greater social harmony in the community and the data in Figures 65 and 66 show the community is less concerned about chemical drift.

Fines

Details on fines imposed by environmental regulators are not readily available. Since 2006 been no fines in relation to pesticides breaches in NSW (NSW EPA, pers comm. January 2009). There has also been no fines related to the Water Management Act 2000 in NSW. (NSW State Water, pers comm. January 2009).

SUMMARY

Key social sustainability indicators include education levels, demographics, employment, health, community attitudes, social capital, research and development and compliance with the law.

Education

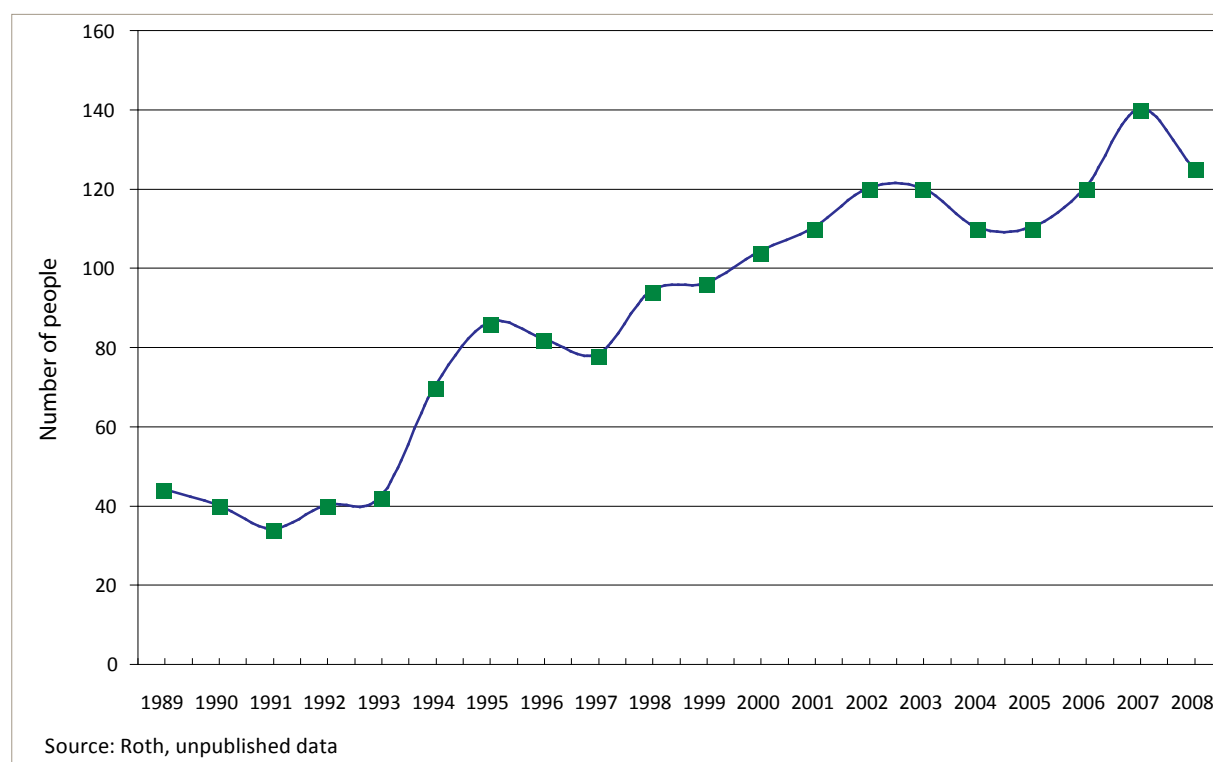
The education qualification levels of the cotton industry are higher than other agricultural industries. The proportion of cotton growers with a bachelor degree is 21.9% and has risen 8.4% in the last 15 years, compared to 16% for the balance of other agricultural industries. A review of Crop Consultants Australia membership shows 64% agronomists have a bachelor degree, while 20% have a Graduate Certificate or higher

Table 34 Crop size and research and extension expenditure by Cotton Research and Development Corporation

	2003–04	2004–05	2005–06	2006–07	2007–08
Crop size (million bales)	1.5	2.8	2.6	1.2	0.6
Research and extension expenditure (\$ millions)	11.3	11.1	11.1	10.1	8.7

Source: data modified from CRDC 2008

Figure 73 Staff numbers at the Australian Cotton Research Institute, Narrabri



qualification. UNE and the Cotton CRCs have offered a Graduate Certificate and Certificate in Rural Science (Cotton Production) and 132 people have completed the course at Graduate Certificate Level, while 69 people have completed it as an undergraduate certificate award.

Several training initiatives are underway in the cotton industry and participation rates are between 20–80% depending on the course. Recent training initiatives include;

- 221 have completed the integrated pest management short course of which 146 achieved the statement of attainment;
- 170 people the 'Cotton Field to Fabric' course;
- 109 people have completed the cotton industry skills development pilot project in 2007;
- 15 people BMP Diploma of agriculture;
- 185 people have completed the cotton and grains irrigation management workshop series;
- 80% of growers had attended spray application courses; and
- 60% had attended OH&S training.

Employment

The cotton industry is one of the leading employers in communities where it is grown. The specific number of people employed by the cotton industry is not clear. It is estimated as 10,000 people. One survey found a typical farm employs 8.5 people, of which 4.8 people were full time, 1.0 part time and 3.2 were casual. Another survey has found over 10 years that 132–185 hectares of cotton is produced per permanent employee with no obvious trend.

The cotton industry generates many permanent and casual jobs, although labour demands are falling. There are several forces interacting that are leading to less employment on cotton farms. These are rising wages, OH&S risks, difficulties recruiting people, and new technology. The drought has also significantly reduced employment in the cotton industry by 30–60%, whilst the mining and energy boom is also attracting people away from agricultural employment. Trends in technology are leading to less employment on farms. Bollgard® transgenic cotton requires less spraying and crop checking compared to conventional varieties.

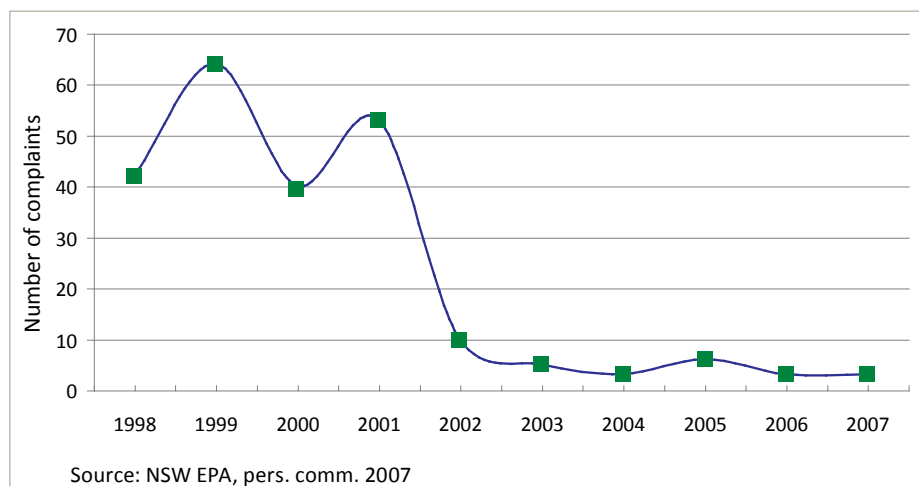


A total of 221 people completed the cotton industry Integrated Pest Management (IPM) course from 2001 to 2005, with cotton researchers delivering specific components of the course. IPM enables environmentally and economically sustainable pest control using the most effective combination of agronomic tools

Roundup Ready® transgenic cotton has resulted in significantly less cotton chipping for weed control. New irrigation systems such as centre pivots and lateral move systems result in less irrigation labour needs. The next technology to significantly impact employment levels on cotton farms will be the new cotton pickers that produce their own cotton modules, thus reducing labour needs during harvest.

The cotton industry has traditionally provided some of the best salary packages in agriculture both on farms and in the service sector. The 2006 Census data showed that 33% of cotton growers, while only 15% of other farmers earned over \$1000 per week. The Census also showed that 75% of cotton growers have been working more than 40 hours per week, which is considerably more than the national average.

Figure 74 Number of complaints received by the NSW EPA 1998–2007



Health

Evidence of a healthy and safe industry and workplace is a component of a sustainable industry.

Health is improving. Deaths rates in the cotton industry are very low, and in the last few years were generally less than 2 per year. Deaths are usually associated with vehicles or cotton ginning. On cotton farms most accidents are associated with machinery operation (28%), while cotton ginning accidents are also high at 25%. The most common agent of injury was the workshop, mobile plants, hand tools, and fixed plant equipment. Workers compensation claims for the last few years have been falling, but so has the planted cotton area. This will need to be verified as the planted cotton area increases again. Nevertheless, there is evidence of improved workplace safety practices.

Demographics

The number of cotton farmers has been falling and it is estimated there are now 800 cotton growers in Australia. Cotton farmers are younger than other farmers that do not grow cotton. Forty percent (40%) of cotton growers are aged under 35 years old, compared to 26% of other farmers while 3% are 65 years old or older, which compares to 11% for other farmers. Most of cotton agronomy consultants were aged between 35 and 49 (65%).

There is greater participation in cotton industry by women. Cotton Australia and CRDC have both had women undertake the role of Chair of the Governing Board and have had 1–2 female Board members in the last five years, which represents about 20% of the membership. Women occupy a number of senior positions in the industry, while at the coal face the cotton industry has many young women in roles such as agronomists and in cotton marketing. The number of women working in three key industry organisations (Cotton Australia, CRDC, Cotton CRC) is greater than 50%. The number of women working as agronomists in the field is much lower at 15%. Compared to other agricultural industries participation of women is high.

Within communities where cotton is grown a significant proportion (10–20%) of the population are aboriginal people compared to the Australian average of 2% of which half of the proportion of the aboriginal populations were less than 19 years old. Some other demographic indicators of cotton communities include the median household income is less than State averages, populations have been declining in most cotton regions and towns since 1991 and higher than state average youth unemployment. Most of these trends are symptomatic of rural Australia in general. Most data is available for the community or local government level, so it reflects all agents of change such as grain, cattle, mining, rather than trends specifically related to cotton industry.

Community attitudes

Community attitudes are important as they influence the social licence or right to farm cotton. People in cotton communities held a positive opinion of the cotton industry. Most people outside the cotton industry have a negative attitude towards the cotton industry and their main concerns were water allocations and pesticide usage. Other concerns were groundwater depletion, wildlife corridors, salinity, spray drift, water quality and genetic modification of food crops, although they were more

comfortable with the its use on fibre crops. The acceptance of transgenic cotton will play a critical role in the future sustainability of the cotton industry. Independent attitudinal research into the cotton industry shows that chemical use, spray drift and high water use concerns had reduced significantly between 1998 and 2004.

Social capital

Social capital refers to features of social organisation, such as networks, and cooperation for mutual benefit. The cotton industry has very high levels of social capital and consists of many well supported organisations. The Australian Cotton Industry Council provides a forum for the many organisations to share information and discuss matters of mutual interest. Each cotton growing region has a Cotton Growers Association. At the industry level there is the Australian Cotton Shippers Association, Crop Consultants Australia, Cotton Australia, and the Cotton Catchment Communities CRC. Recently, a women in cotton organisation known as Wincott was formed. Further evidence of the social capital of the cotton industry are the delegate numbers at the biennial Australian Cotton Conference. Fourteen conferences have been held and it is the largest conference of any agricultural industry in Australia with usually over 1000 delegates. Technology has played an important role in the social capital of the cotton industry. Faxes, mobile phones were rapidly adopted. These days 99% of grower have access to the internet and internet usage of industry sites has doubled in the last three years despite a declining crop area.

Research and development

The Australian cotton industry has a strong research and development culture. Expenditure levels have generally been around \$11 million per year, although they have been less in recent years due to the drought and reduced production. Cotton growers pay a \$2.25 per bale research and development levy, which is managed by the Cotton Research and Development Corporation. The cotton industry has also been an active participant in the Australian Government's Cooperative Research Centre program and the Cotton Catchment Communities CRC will operate until 2012. The staff numbers at the Australian Cotton Research Institute, Narrabri, have grown from 40 people in 1990 to currently around 120 people. The cotton industry provides a number of scholarships for educational, training and professional development and for example has supported 199 Post Graduate scholarship projects have been completed or are underway since 1990, most of which were PhDs (>95%).

Legal compliance and responsibility

The number of breaches of environmental laws are not widely reported by Government agencies, although individual cases usually attract plenty of publicity at the time of prosecution. The number of complaints received by the NSW EPA has fallen from around 50 per year in 2001 to 3 per year for 2006 and 2007. Less complaints leads to greater social harmony in the community and supports the data that the community is less concerned about chemical drift and spraying. Since 2006 been no fines in relation to pesticides application. There have been very few, if any prosecutions related to water licence breaches and vegetation clearing in the last few years. There is no public database for this information.

6 THE COTTON BEST MANAGEMENT PRACTICES PROGRAM: CHANGES IN FARM PRACTICES

THE COTTON BEST MANAGEMENT PRACTICES PROGRAM

Overview

The Cotton Industry's Best Management Practices (BMP) Program is a voluntary environmental risk management program based on a process of continuous improvement using a 'plan-do-check-review' management cycle. Cotton Australia (2006) describes it as a "functional environmental management system". An overview of the Cotton BMP program by Cotton Australia (2006) outlined the program goals as:

To see the development of the cotton industry:

1. *whose participants are committed to improving farm management practices;*
2. *whose participants have developed and follow policies and farm management plans that minimise the risk of any adverse impacts on the environment or human health;*
3. *which can credibly demonstrate to the community stewardship in the management of natural resources and farming operations.*

The Cotton BMP Program presents the opportunity for the cotton industry to demonstrate and provide more confidence to the community, governments and cotton markets in its ability to use and manage various technologies such as pesticides and gene technology (Anthony 2004). The BMP Program also provides a systematic process for the cotton industry and its growers to contribute to the catchment planning and natural resource management goals of Government. It is a proactive initiative that is enhancing cotton growers' social licence to farm (Higgins and Adcock 2008).

The background and development of the Cotton BMP Program is described by Williams and Williams (2001), Williams *et al* (2004), Ross and Galligan (2005) and Schofield *et al* (2005). It was introduced to primarily improve the management of pesticides. BMP



then evolved to address broader natural resource management issues related to land and water management and recently the Queensland Department of Natural Resources and Water recognised BMP certification as an alternative pathway to develop a statutory Land and Water Management Plan as required by the Queensland Water Act (Higgins and Adcock 2008).

The Best Management Practices Manual is primarily designed to help cotton growers identify and manage the environmental risks associated with their business. The Cotton BMP program consists of seven modules:

- Application of Pesticides;
- Storage and Handling of Pesticides ;
- Integrated Pest Management;
- Farm Design and Management;
- Farm Hygiene;
- Petrochemical and Storage; and
- Land and Water Management.

The first four modules formed the content of the original BMP Manual, released in 1997 where the focus was on managing pesticide use. In 2000, these modules were revised and a farm hygiene module was released. These five modules were further updated in 2002 and a Petrochemical Storage and Handling module was released to cater for many environmental and OH&S issues associated with oil and fuel. The Land and Water Management module was released in 2005.

Most recently, the cotton industry has been investigating the use of BMP program post farm gate such as for ginning and transport. The implementation of BMP at grower level and the use of it throughout the supply chain provides a vehicle and standards for the improvement of Australian cotton product (Dall'Albra 2006). The cotton industry has investigated the cotton market requirements of retailers (Williams 2007). Work continues by the Australian Cotton Shippers Association and Cotton Australia to evaluate the promotion and marketing of "BMP Cotton" as environmentally responsible cotton (Spellson 2008).

Consumers are seeking "eco fabrics" and demand for perceived environmentally friendly fibres continues to grow (Fitzpatrick 2008). The Japanese retail company Izumiya has been buying BMP cotton to market a line of baby clothes called "lifestyle of



Japanese retailers, Izumiya, are now sourcing only Australian BMP cotton for their in-house environmentally branded 'Good-i' clothing

health and sustainability". The Cotton BMP offers the Australian cotton industry a means to offer traceability, sustainable production practices and high quality cotton in the world textile market. However, it will be some time (many years) before any premium price is paid to growers (Spellson 2008).

The BMP program has posed many challenges. Some of the weaknesses of the BMP Program include that many growers see it as difficult and intrusive, it is less relevant to current issues, there is no direct financial gain, there are benefits to the industry but not individuals, and that there has not been effective measurement and communication of changed farm practices.

The Cotton BMP program is currently adopting a new strategic direction to maintain its relevance to farming businesses. A revised structure will include water, soil, chemicals and IPM, carbon and energy, bio-security, technologies, natural assets and human resources (Higgins and Adcock 2008). It will also be delivered via the internet.

The process of the Cotton BMP Program on farms

The Cotton BMP program incorporates a risk assessment process, which involves identifying hazards, assessing risk and the development of an action plan. The program modules explain the best practices for each topic, why they are important and any legal obligations. Best practice recommendations are also provided for growers to improve their management. The program includes self-assessment worksheets which provide a systematic approach for growers to follow. Growers rank their practice on a scale of 1 (best) to 4 (worst). For practices with rankings of 3 and 4 growers are required to develop an action plan on how they intend to improve this specific practice in the future.

Cotton Australia funded field staff to help growers through the process. The Australian Government has also supported the program through various initiatives which are summarised by Ross and Galligan (2005). Other organisations provide technical support and program development including the Cotton Research and Development Corporation, Cotton Catchment Communities CRC, regional natural resource management bodies and state agencies. The BMP program has evolved with considerable input by industry and stakeholders. Papers by Williams *et al* (2004), Ross and Galligan (2005) and Schofield *et al* (2005) explain the many changes that have been made to the program. Spanswick (2006) outlined the challenges and rewards with the new BMP Land and Water module.

Auditing of the Cotton BMP Program

The BMP program includes a voluntary audit program, which was established to objectively and independently verify the on-farm implementation and compliance of the program (Holloway and Roth 2003). The auditing process of the BMP Program began in May 1999. Auditors were trained by the industry to ensure that they have skills both in environmental auditing (with a course recognised by the Environmental Auditors Association) and in cotton farming systems. The audits process is managed by Cotton Australia.

The audit process has evolved over the years. Cotton Australia (2006) outlined the current audit process as:

- **Pre-Certification Assessment (PCA):** The first stage in the path to BMP Certification is the PCA. The PCA involves the grower undertaking a risk assessment of their operation and preparing action plans for those issues identified as posing a significant risk. PCAs are conducted by Grower Services Managers and become a formal record designed to assist the grower benchmark current practices, identify areas of improvement and prepare action plans that will, if followed, result in the grower improving practices and meeting or exceeding BMP certification standards. It is an action stage – it helps defines the priorities of the grower for the coming 12 months.
- **Certification Audit:** Within one year (1) of the PCA the Certification Audit is due to be conducted. Certification Audits are conducted by industry BMP Auditors. Growers are audited against the industry certification standards. Certification is valid for 12 months.
- **Annual Self Assessment Declarations (ASAD):** Growers renew their BMP Certification by completing and submitting to the BMP Office an Annual Self-Assessment Declaration to verify that the certification standards are being maintained. To complete the ASAD, a grower conducts a risk assessment of and action planning for the operation, as was done in the PCA process.
- **Random Surveillance Audit:** To monitor the effectiveness of the Annual Self Assessment Declarations and the re-certification process as a whole, random surveillance audits across certified farms are also conducted. Random Surveillance Audits are conducted by industry BMP auditors and follow the same procedure as Certification Audits.

In 2004, the industry BMP Committee resolved that the Petrochemical and Land and Water Management modules would be voluntary to include in certification audits for a period of three years, to allow time for growers to adopt, particularly those that hadn't yet started the BMP Program and would be facing all 7 modules at once. From January 2008, certification for all seven modules is required to be certified to the BMP Program. There is a separate OH&S companion system; however this is not formally part of the BMP Program.

Monitoring of Cotton BMP achievements

Since the introduction of the Cotton BMP Program in 1997, independent reviews have found that at least 85% of cotton growers have changed their practices as a result of the BMP Program. Of the approximately 850 cotton enterprises currently registered with Cotton Australia, 12% are currently certified and a further 32% are at a pre-certification assessment stage, working towards certification (Cotton Australia, pers. comm., 7th October 2008). Table 35 shows the trends in the number of certified farms. In 2002, 33% of cotton growers were certified BMP compliant, which rose to 46% in 2006, however by 2008 this had fallen to 12%. The fall is partly due to the drought, but also the need to update the program with more relevant issues.

Achievements of the BMP program have been monitored in a variety of ways including:

- surveys of growers;
- surveys of audits;
- the Second Cotton industry environmental audit (GHD 2003);
- reviews of the BMP Program (Macarthur Agribusiness 2003; Hassall & Associates 2006); and
- analysis of published reports and data.

In May 2006, Cotton Australia undertook a survey of 70 growers both levy and non-levy payers, BMP participants and non-BMP participants (Cotton Australia 2006b). The result showed that 79% of the growers felt that BMP had improved the environmental performance on their farm, 31% of growers felt BMP had improved the financial performance of their farm, while 46% indicated it had improved staff management.

Cotton Australia also asked the growers what they thought the industry could do to get other growers to adopt BMP. The key ways for industry to support growers in adoption of BMP is to demonstrate its benefits, develop grower champions and grower to grower encouragement as well as providing incentives and discounts.

The audit process has posed challenges in its management (Hassall and Associates 2006).

Holloway and Roth (2003) reviewed the grower feedback on audits and found that 90% of respondents felt an audit was of significant benefit. Some grower comments on the benefits of the audit program included: "it makes you aware of your obligations, it focused on the issues we overlooked, it gave us the push to do things we have been putting off." This was significant feedback at the time as auditing was often stated as a barrier and unnecessary aspect of the program.

In 2003, CRDC commissioned GHD Pty Ltd to conduct the second environmental audit of the Australian cotton industry (GHD 2003) and to assess the industry's response to the previous environmental audit in 1991 (Gibb 1991). The 2nd environmental audit involved a review of the literature, workshops with stakeholders and visits to 32 farms.

As noted in the 2nd Environmental Audit of the Cotton Industry by GHD (2003):

"One of the most significant environmental improvements in the Australian Cotton Industry was the development of the BMP program. The audit identified a direct link between areas of improvement observed on the properties and the BMP modules. Farms that had undertaken their second BMP audit showed real improvements in environmental management and the auditing process provided a benchmark to indicate that progress had been made. The BMP audits were found to give a good assessment of the environmental farm practices currently covered by the manual".

The environmental audit recommended that key environmental performance indicators by which the performance of the cotton industry as a whole, and at individual farms can be objectively assessed need to be developed.

Macarthur Agribusiness (2003) was commissioned by CRDC to undertake an evaluation of BMP outcomes. The evaluation involved 10 farm visits, 65 telephone interviews, and focus groups in five cotton regions. The report found:

- Significant beneficial change in cotton farm practices since the manual was introduced in 1997 such as improvements to IPM, pesticide application, communication, weather monitoring, reduced pesticide use, reduced spray drift and odour complaints, improved water quality and a reduction in fish kills and cattle contamination;
- On farm economic outcomes are difficult to quantify, which was a similar conclusion reported by Cotton Australia (2006). They were often viewed as things growers would have done anyway;
- External stakeholders regarded the audit program as important; and
- That audit data be used for triple bottom line reporting.

Hassall and Associates (2006) evaluated the implementation of the BMP process and in particular the BMP Land and Water Module. The study identified that it was too early to judge the environmental outcomes of the land and water module at the time as very few growers had progressed with its implementation. At that time (January 2006) 27% of growers had had some exposure to the module and only 8% had progressed to the pre-certification audit. Most growers interviewed felt they were really quite unfamiliar with the land and water module. During 2006, increased impetus to the BMP Program by Cotton Australia led to 128 new growers entering the BMP program and undertaking a pre-certification audits (Cotton Australia, pers. comm.)

The Hassall and Associates (2006) study found that growers and stakeholders considered the BMP process and the Land and Water Module to be effective well developed tools for reviewing and planning changes to activities on farm. It also found the Land and Water Module effectively addresses most key natural resource management issues relevant to the cotton industry and made several recommendations to improve BMP uptake by growers. Likely outcomes included changes in attitude, knowledge and aspirations as well as natural resource management outcomes such as water use efficiency and soil health. Most growers felt that BMP Land and Water would have some small influence on their NRM outcomes. The right to farm and continued access to water were found to be the largest potential benefits for production and profitability. The study reviewed the BMP Land and Water module against regional catchment targets and discussed the gaps and opportunities. Another value of the program was that it provided a means to implement best practice as well as benchmark and quantify environmental performance.

Table 35 Proportion of cotton growers compliant with the Cotton BMP program

AUDIT / YEAR	2002	2006	2008
Certified compliant	33%	46%	12%
Pre-certification compliant	18%	n/a	32%

Source: Cotton Australia 2002 ; Cotton Australia 2006: Cotton Australia 2008 pers. comm.

By the end of 2006, 46% of the Australian cotton crop was being audited according to the BMP guidelines (Cotton Australia 2006). CCA (2007) reported that there are some significant difference between growers who chose to formalise their BMP accreditation, and those who follow the guidelines but are not accredited. BMP accredited growers were more likely to measure water use efficiency, monitor groundwater levels, use soil testing and pits, plant native vegetation, and provide alternative watering points for stock near the riparian zone. The CCA (2007) survey also found the BMP growers tended to have larger areas of cotton compared to non accredited growers. Just over half (51%) of accredited growers had completed tertiary education compared to 31% of the non accredited growers.

When incentive funds from government are linked to the BMP program to make changes these rewards can be substantial. Spanswick and Jones (2008) found that water use efficiency improved by 15% or 5000 megalitres over 8000 ha of cotton in Namoi Valley. Ross (2008) in Cotton Australia's 2007–08 Annual report lists the outcomes of the BMP program in 2008 as:

- 10 consultants and 14 growers had participated in WUE training;
- 69 properties in the Namoi Valley were provided sophisticated farm maps and 22 properties were provided with groundwater monitoring data;
- BMP objectives were mapped against the nine local regional natural resource management bodies' organisational catchment target;
- Increased effort to link cotton and grain BMPs; and
- BMP certification as an alternative pathway to develop a statutory Land and Water Management Plan enshrined in the Queensland Water Act.

The World Wildlife Fund (WWF 2005) wrote an assessment of the Cotton BMP program including strengths, limitations and lessons learnt from their participation in the development of the land and water module. WWF recommended the collection of baseline data to monitor changes to the environment. WWF also noted that while there was a central register of the BMP files, the industry was not collating and tracking the results. Hence, the impetus for the following analysis done for this study in the next section of this chapter.

AN ANALYSIS OF THE COTTON BMP AUDIT DATA 1999–2008

This section reports an analysis of the Cotton BMP audit data conducted for this study. The aim was:

- To identify and quantify how BMP cotton growers have changed their farm management practices since the inception of the BMP program.
- To establish if the BMP audit rankings can be used to track and report farm management practice change.

Materials and methods

The Cotton BMP risk assessment process involves identifying hazards, assessing risk and the development of an action plan. The manual includes self assessment worksheets which provide a systematic approach for growers to follow. Growers rank their practice on a scale of 1 (best) to 4 (worst).

The Cotton BMP program includes a confidential audit process with audited reports kept at Cotton Australia. To obtain access to this information and undertake this analysis the author signed a non disclosure and privacy statement to ensure identification of any specific farm data and farm identification was not disclosed during this research project or reported at its conclusion. The author undertook training during the course of this study in environmental auditing to the ISO 14001 standard.

The audit files are each typically 10–15 pages in length per farm. For the first five years of the program these assessment rankings did not form part of the audit report and were only provided at the discretion of growers. It was necessary to examine each paper file of the BMP audited farms and identify the growers that had provided their audit farm practice data rankings to the BMP Office. The audit report template was revised in 2003 to include the ranking data.

The 47 farm practice rankings were manually compiled into a spreadsheet so that the rankings on grower practices could be collated and examined for modules 1–5. The farm practice rankings audited using the first edition of the BMP manual (CRDC 1997) were realigned so they could be compared to audits conducted using the system of the BMP manual second edition (CRDC 2000b).

The petrochemical storage module, which includes seven objectives and land and water module, which includes 25 objectives, were not externally audited until 2008. A few growers were audited in 2007 as part of the development of the program. Hence, they do not feature in the results related to the certification audits.

Data for farms that had been audited more than once between 1999 and 2008 were collated and compiled into a data set for Modules 1–5. It was possible to compile data for 86 farms, which is about 10% of the cotton industry. These growers were responsible for 40% of the total amount of cotton produced in Australia. By limiting the data to those farms which had been audited twice it enables a better comparison over time of how they have changed.

In 2006, the concept of a pre-certification audit was introduced to encourage more growers into the program and included all seven modules. These were free audits conducted by the Cotton Australia Grower Services representatives. Data from 210 pre-certification audits between 2006 and 2008 were compiled into a spreadsheet so the results could be examined.

The remainder of this Chapter provides the results and discussion of the analysis

Aggregated results for the initial BMP modules

The average BMP ranking was 1.46 for all 47 farm practice criteria between 1999 and 2008 for the pesticide application, pesticide storage, IPM, farm design and farm hygiene modules is shown in Figure 75. There was a 29% average improvement in the BMP rankings between 1999 and 2008 of cotton farm practices. The results show a 45% improvement in the average BMP ranking between 1999 and 2006 which is when the BMP Program had strong political and financial support from the

cotton industry and some additional financial support from the Australian Government.

The slight drop in BMP rankings in 2002 may be due to the 2002 drought when the area of cotton reduced significantly to 200,000 ha, down from previous three seasons of 400,000 ha. The cotton crop area rose again to 300,000 ha in both 2005 and 2006.

There was a significant fall in the mean BMP rankings in 2007 and 2008. In 2007, drought reduced the crop area significantly to 110,000 ha and in 2008 it was the lowest in 30 years at 64,000 ha. The drought has two related impacts. Firstly, it meant that farms were less profitable and hence business cost cuts were made for growers to remain viable. Secondly, the cotton industry collected less income via its production based levy and therefore less staff were available to help growers implement BMP actions. Contact by industry BMP staff provided a trigger for cotton growers to action specific practices especially those relating to paperwork and communication. Between 2008 and 2009, the cotton industry recommitted itself politically to BMP and despite the drought, it was given higher priority than in the previous 2007 season. This could explain the improvement in the BMP rankings in 2008.

Generally, a BMP ranking of one or two complies with the BMP Certification standard set by the cotton industry and it meets legal requirements. The data in Figure 75 shows there has been a high standard of legal compliance on BMP farms between 1999 and 2008.

The following sections of this report examine trends related to each specific BMP module.

Pesticides application module

The aim of the pesticide application module is to improve the safety for people and reduce off target impacts on the environment when working with agricultural chemicals. Figure 76 shows that on average there was a 7% improvement in the 19 pesticide application management practices between 1999 and 2008. Prior to the 2007 & 2008 drought, between 1999 and 2006 there was a 31% improvement in the 19 pesticide application practices of the module. The data shows that BMP cotton growers were complying with a high standard of best practice with a mean BMP ranking of 1.4 between 1999 and 2006. However, in 2007 and 2008 there was a lower level of compliance when the mean BMP ranking rose to 1.7. This is attributed to the drought, which had caused significant loss of well trained people in BMP procedures and also meant there were less staff in general to undertake farm management tasks.

Trends of each of the 19 objectives in the pesticide application module are shown in Figures 77–81, on the following pages. The centerpiece of the pesticide application module is a pesticide application management plan. A pesticide application management plan requires the identification of risks, good communication, appropriate application techniques and record keeping. Figure 77, on the following page, shows that the mean BMP practice ranking for pesticide application management plans was 1.35 between 1999 and 2006. In 2007 and 2008 the mean BMP ranking

Figure 75 The mean Cotton BMP audit rankings for all 47 farm practice criteria between 1999 and 2008 from the pesticide application, pesticide storage, integrated pest management, farm design and farm hygiene modules

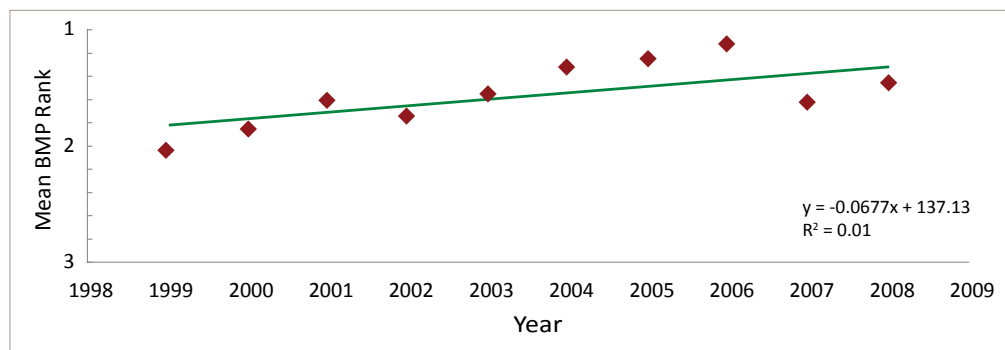
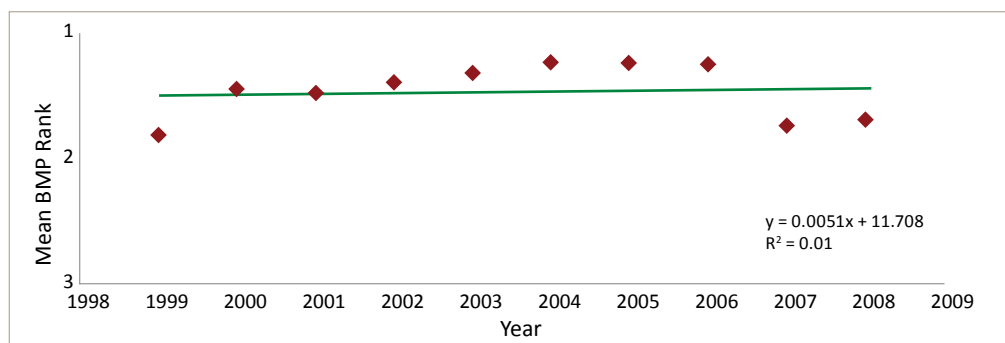


Figure 76 The mean Cotton BMP audit rankings for all application of pesticides module farm practice criteria between 1999 and 2008



rose and averaged 1.85, which was 40% worse than the previous eight years, but still a high level of compliance. A ranking of one means the pesticide application management plan is used for all pesticides. A ranking of two means it is only used for restricted chemicals, usually for the insecticide endosulfan where there is a legal requirement to have a plan. A ranking of 3 and above means the grower does not have a plan.

A farm map is used to communicate and plan activities. The quality of farm maps was high on BMP farms, which had an averaged BMP ranking of 1.6 and did not change between 1999 and 2006. There is a similar trend to the pesticide application management plans that in the last two drought years (2007 & 2008) the map quality has not been as good as in previous years as the mean BMP ranking rose to 1.85. A ranking of 4 means there is no map, while a ranking of 3, which is the certification standard, means there is a map which includes on-farm buildings and sensitive areas such as water courses. A ranking of one and two means there is more detail on the maps, including the land surrounding the farm.

The BMP program introduced the requirement of pre-season communication with neighbours, consultants, chemical applicators and farm workers. Figure 78 shows no obvious trends in relation to pre-season contact with neighbours, consultants and applicators over 10 years, with the exception that there was a lot less communication during the drought years of 2007 & 2008. The results with a ranking lower than two mean they comply with BMP certification standards. Pre-season communication with neighbours had improved since 1999 between 2000 and 2006. Pre-season communication with workers had steadily improved over the 10 years. With the tightening of OH&S laws, growers have become more diligent in communicating with staff. A BMP ranking of two means a pre-season meeting has taken place and it has been recorded on paper. A ranking of one requires a range of very specific issues to be discussed and recorded. A rank 4 means that no meeting took place, while rank 3 there was a meeting, but no details were recorded.

Figure 77 The mean BMP rankings for pesticide application management plans and farms maps on BMP audited cotton farms over 10 years between 1999 and 2008

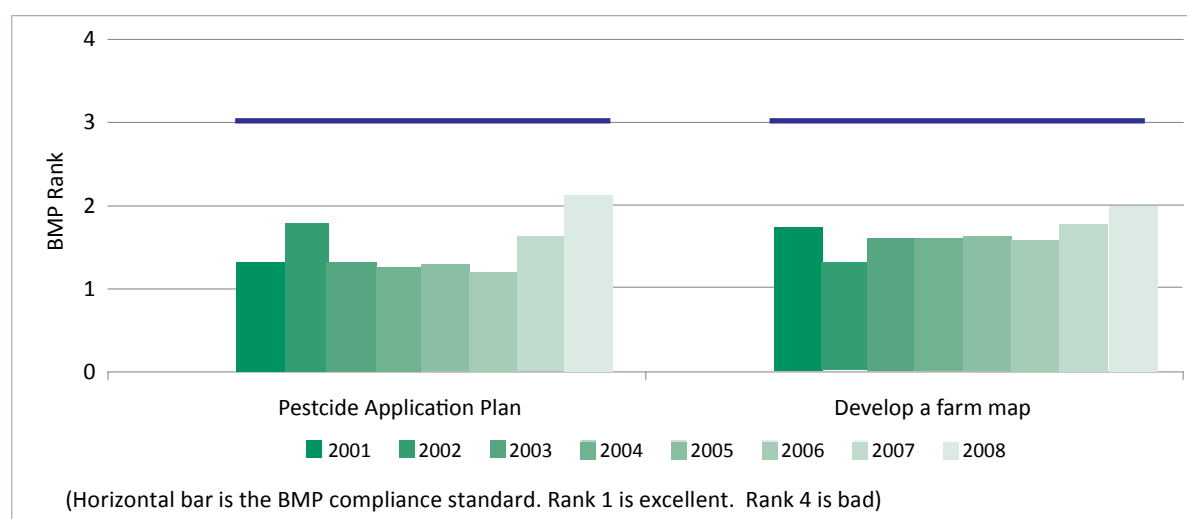


Figure 78 The mean BMP rankings for pre-season contact with neighbours, consultants, applicators and workers on BMP audited cotton farms over 10 years between 1999 and 2008

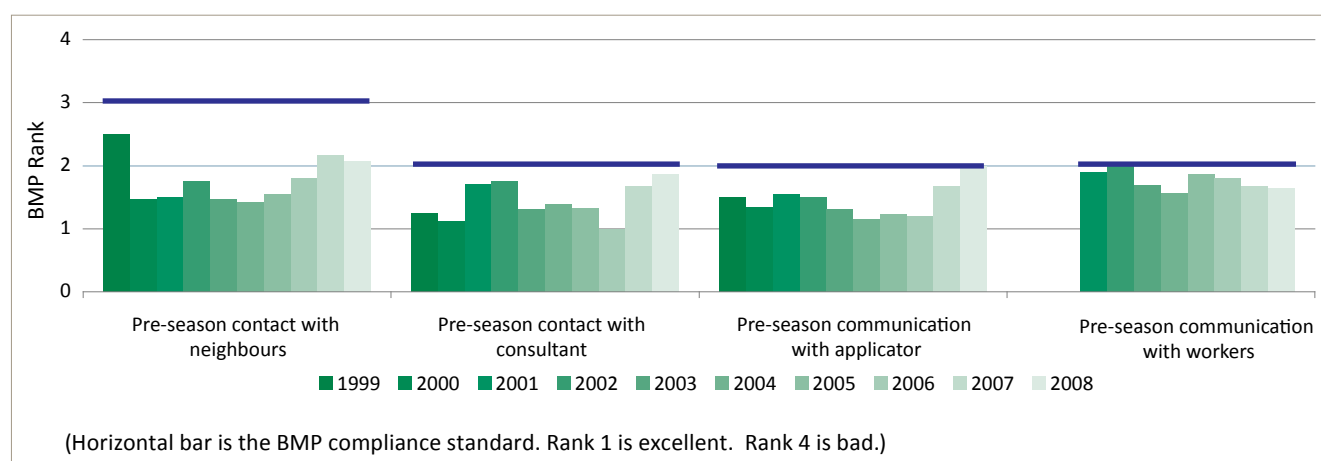


Figure 79 shows there was a trend of steady improvement of “in season” communication with neighbours, consultants, applicators between 1999 and 2006; however, for 2007 and 2008 the in-season communication was less, again caused by the drought. Coutts *et al* (2001) also noted improved communication between consultants and growers between 1997 and 2001. A ranking of 4 means communication rarely takes place. A ranking of 3 is the BMP certification level. A ranking of 2 means discussion took place, while for a ranking of one, the discussions took place and actions were written down. Thus, the standard of in-season communication was high, but to further improve to a BMP ranking of 1, actions need to be written down. Many growers do not see the extra step or writing down details as achieving any practical outcome, although they might in the future if spray drift litigation increases.

Worker awareness of pesticide applications remained high with a mean BMP ranking of 1, which is the certification level (Figure 80). Between 1999 and 2006 there were improvements in determining weather conditions (54%), and in monitoring weather conditions (46%). To meet the BMP certification level rank 2, growers need to have monitored the weather and recorded it. To obtain a rank 1 they need to have a wind sock installed. There

was less monitoring and recording of the weather in the drought years of 2007 and 2008. The application of pesticides in appropriate conditions, which has a certification level of rank 3, shows a trend of improvement between 1999 & 2006, but increased in the drought years of 2007 & 2008. The mean rankings always remained below a rank 2, which meant growers applied pesticides in appropriate conditions.

The pesticide product choice has been of a high standard and improved each year (Figure 81, on the following page). A ranking of 4 would mean no consideration is given to offsite damage or for the resistance management strategy. A ranking of 1 means the use of all products takes into account potential off site damage and the resistance management strategy. The BMP certification level for the training of applicators is a ranking of 2, which meant all people using or handling pesticides hold a current Chemcert certificate. To obtain a ranking of 1, supervisors need to also hold a certificate. Between 1999 and 2006 there was 33% improvement in training of applicators. However, in 2007 and 2008 the rankings increased, which meant fewer people held Chemcert certificates, again possibly caused by cost cutting during the drought.

Figure 79 The mean BMP rankings for in-season communication with neighbours, consultants, applicators on BMP audited cotton farms over 10 years between 1999 and 2008

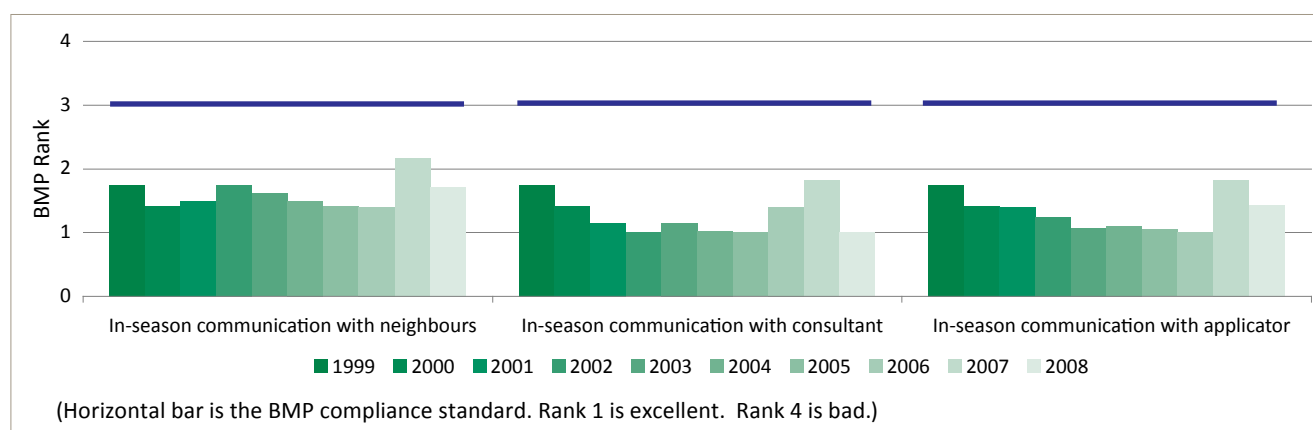
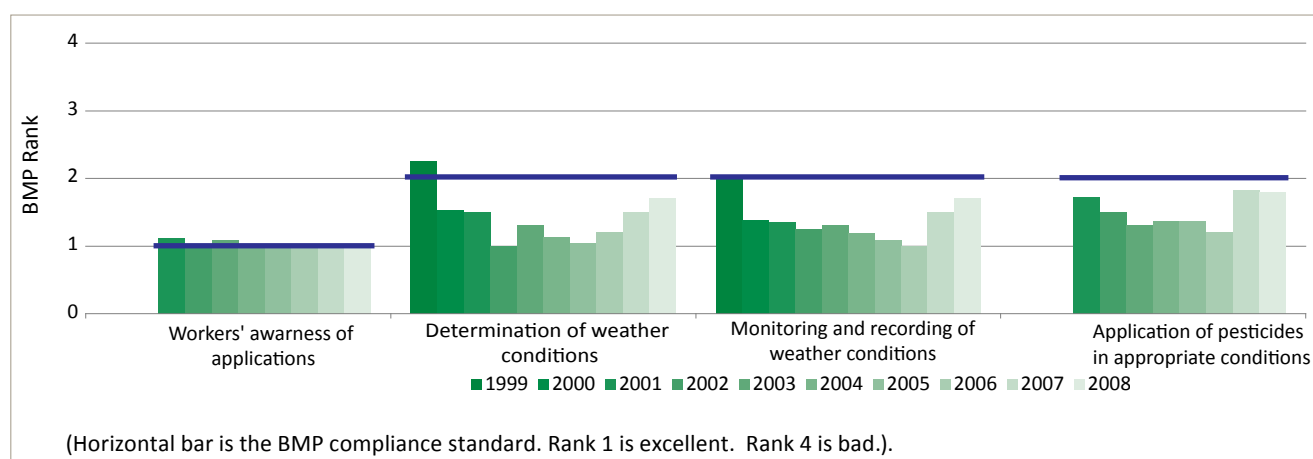


Figure 80 The mean BMP rankings for worker awareness of applications, determination of weather conditions, monitoring and recording of weather conditions and application of pesticides in appropriate conditions on BMP audited cotton farms over 10 years between 1999 and 2008



Between 1999 and 2002, the growers mean BMP ranking for following label directions was near 2. This improved considerably between 2003 and 2006 to a rank 1, but rose back to 2 in 2007 and 2008. A ranking of 4 means labels are not followed, a ranking of 2 means labels are followed, but some material safety data sheets (MSDS) sheets are not available, while 1 means labels are followed and MSDS sheets are available for all products. The BMP certification level is a ranking of 1.

Equipment choice and calibration followed similar trends and the rankings remained below 2. This means equipment is calibrated before each application and weather monitoring equipment is checked annually. To obtain a ranking of 1, the weather monitoring equipment must be checked regularly. Rank 3 is the BMP certification level, thus BMP growers have maintained a high standard of compliance.

Record keeping is a critical part of the BMP program and growers in the program have maintained a high standard of compliance. It is important for checking the effectiveness of procedures, complying with regulations for some activities and it is a means of demonstrating due diligence. A ranking of 1 is the BMP certification level. There has been an improvement in record keeping when comparing 1999 & 2000 with 2001–2006. However, in 2007 and 2008 record keeping rankings rose back to a rank 2, which means most records are kept, rather than all records to obtain

a rank 1. Again this was probably due to the drought and cost cutting. Coutts *et al* (2001) also noted improved record keeping between 1997 and 2001.

Storage and handling of pesticides module

Cotton growers need to store pesticides on their farm safely and in a secure fashion to manage risks to human health and the environment. There was a 45% improvement in the pesticide storage practices between 1999 and 2008 on BMP audited cotton farms (Figure 82). Between 1999 and 2006 this improvement was 56% (Figure 82). There was a small decrease in the mean BMP rankings in the drought years of 2007 and 2008 from 1.2 in 2006, to 1.5 in both 2007 and 2008. Fixing chemical storages is a capital improvement and thus one of the first items to be cut by farmers during tough financial times. There was also a decline in rankings in 2002, possibly due to a number of new growers joining the program who did not have very good chemical storages.

Chemical storages need to be located away from sensitive areas such as buildings and watercourses, and out of flood prone areas to achieve a BMP certification ranking of 2. The storages need to be away from other buildings and have running water to achieve the BMP certification ranking of 3. Figure 83 shows that the chemical storages met this criteria between 1999 and 2008, with the exception of the spike in 2002, which may be due to a

Figure 81 The mean BMP rankings for pesticide choice, training of applicators, label directions, equipment choice and calibration and record keeping on BMP audited cotton farms over 10 years between 1999 and 2008

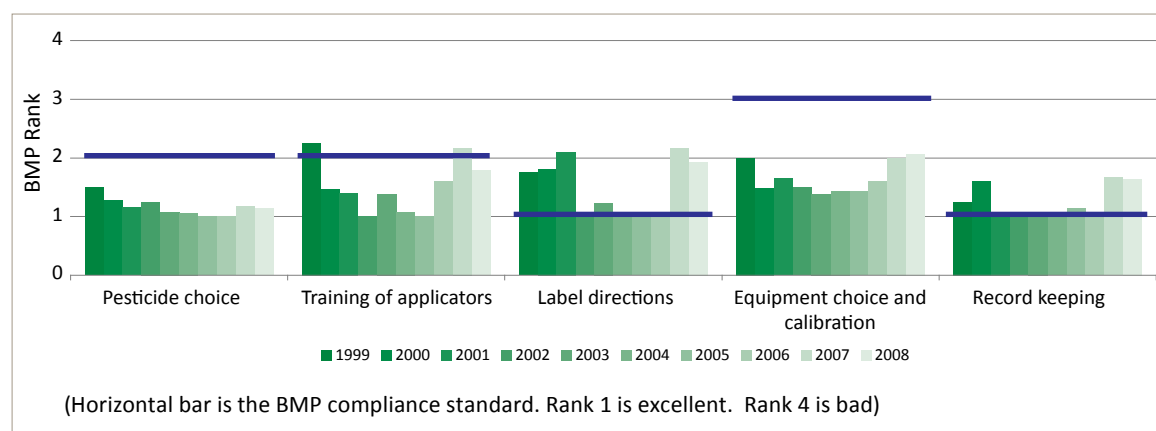
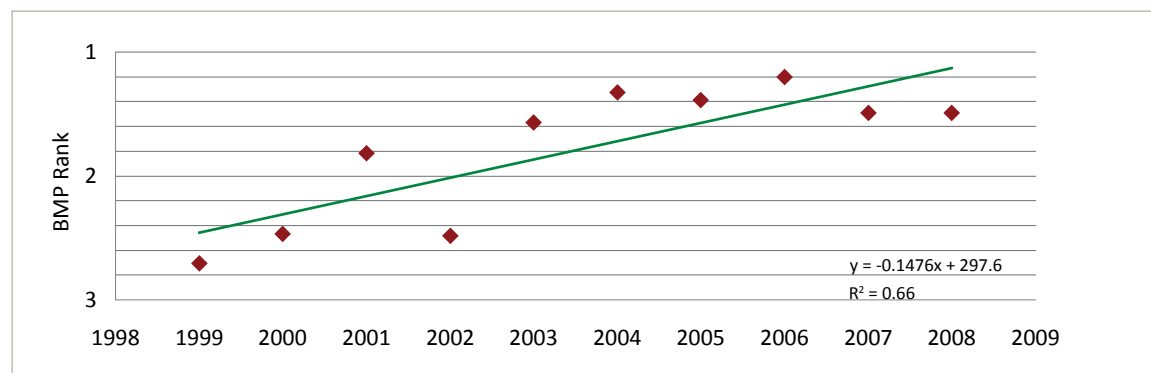


Figure 82 The mean Cotton BMP audit rankings for all the storage and handling of pesticides farm practice criteria between 1999 and 2008



number of new growers joining the BMP program in 2002 that had poorly built and located chemical storages.

Figure 83 shows significant improvements were made between 1999 and 2008 in spill containment (69%), where growers between 1999–2002 had scores around 4 and were clearly not compliant. The BMP certification standard for spill containment is 1 and growers have been close to achieving that in the last three years 2006–2008. Improvements were also made in relation to storage ventilation (49%), security (51%), work procedures (19%) and emergency procedures (39%), which each had a BMP certification standards of rank 2.

Figure 84 shows significant improvements were made between 1999–2008 in signage on chemical storages (38%), mixing and loading sites (62%), mixing and loading systems (65%), worker safety (22%) and waste disposal (35%). Trends for equipment maintenance, and safe transport are not clear, but were of a high standard. The BMP certification standard for signage is 3, mixing and loading sites is 2, mixing and loading systems is 2, worker safety is 1, waste disposal is 2, equipment maintenance is 2 and safe transport is 2.

Integrated pest management module

The aim of the integrated pest management (IPM) module is to encourage cotton growers to use less insecticides and in particular to use broad spectrum insecticides as a last resort. Figure 85 shows the mean farm practice BMP ranking for IPM practices was of a high standard. Between 1999 and 2006 IPM practices improved by 18%. In 2007 and 2008, IPM practices declined by 21% from their best practice in 2006, due to the drought and some cost cutting by growers and their agronomists.

A breakdown of the six objectives in the IPM module is shown in Figure 86. The BMP certification standard is 3 for all of these practices, except the monitoring and sampling where it is 2. The farm practices of managing for early maturity averaged 1.10 between 1999 and 2008. Earliness of maturity was seen as a prime driving force for IPM, hence its inclusion in as a BMP criteria and a key management tactic was to avoid early crop damage. The mean BMP ranking for monitoring and sampling between 1999 and 2008 has averaged 1.24 and reflects the importance the cotton industry has placed on its insect crop checking.

There was a 40% improvement in the consideration and recording of beneficial insects between 2001 and 2006, but in 2007 this

Figure 83 The mean BMP rankings for storage location, storage building, spill containment, storage ventilation, security, work procedures and emergency procedures on BMP audited cotton farms over 10 years between 1999 and 2008

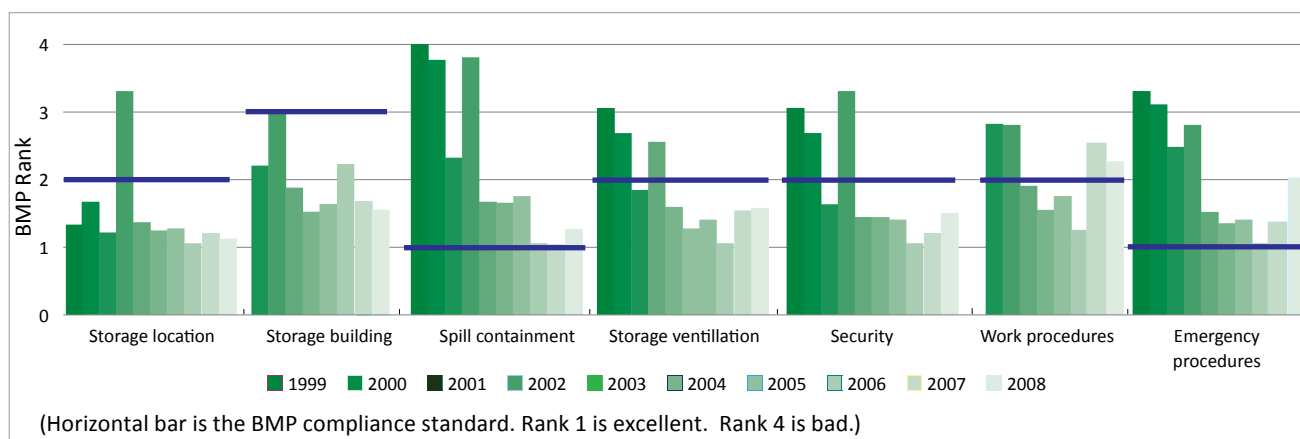
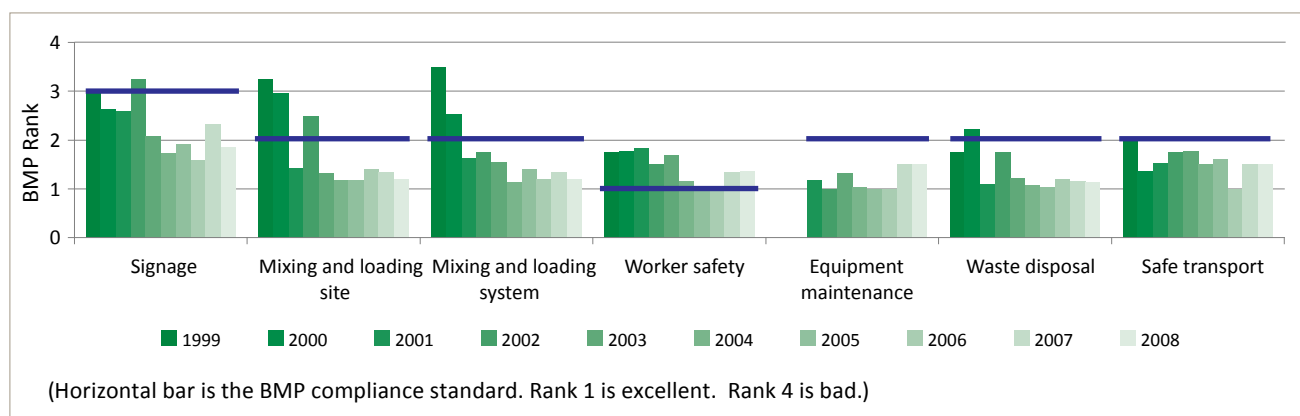


Figure 84 The mean BMP rankings for signage, mixing and loading sites and systems, worker safety, equipment maintenance, waste disposal and safe transport on BMP audited cotton farms over 10 years between 1999 and 2008



practice dropped sharply, but did improve again in 2008. This practice was not part of the BMP program in 1999 and 2000. This is most likely to be due to the drought and the need to cut costs. There was also a high proportion of transgenic cotton planted in 2007 and 2008, which enabled growers to more confidently reduce the amount of insect scouting.

The compliance with the cotton industry pesticide resistance management strategy has been consistently good, with a mean BMP ranking of 1.18 between 1999 and 2008.

Host and trap crop management became part of the BMP program in 2001 and since then mean BMP rankings have improved 17%. The use of host and trap crops has become more common in recent years as it is a compulsory requirement to grow a refuge crop when growing transgenic or Bollgard® cotton varieties.

Area wide management of insect pests became part of the BMP program in 2001 and the mean BMP rankings for each season

since have remained constant, averaging 1.62 over this period. There is no certification standard for this practice as it is not possible for all growers to be members of area wide management groups. The adoption of area wide management practices has declined in the last couple of years and this explains the increased variability in the data trends between 2006 and 2008.

The Cotton CRC conducted a large extension program between 1997 and 2001 on IPM. Coutts *et al* (2001) found key changes to industry attitudes and practices towards IPM. For example, they found greater confidence in the use and understanding of beneficial insects, improved monitoring and sampling and greater use of area wide management groups. Coutts *et al* (2001) noted improved communication between consultants and growers between 1997 and 2001 as one of the key drivers of improved IPM in the cotton industry. Increased adoption of transgenic pest management traits also enabled a high standard of IPM practices.

Figure 85 The mean Cotton BMP audit rankings for all the integrated pest management practice criteria between 1999 and 2008

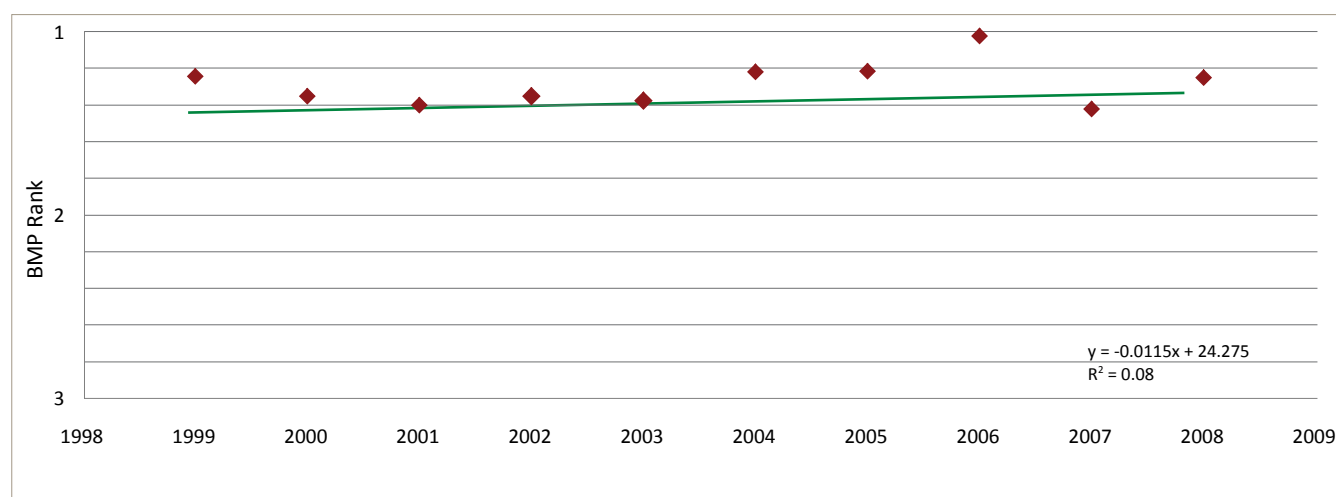
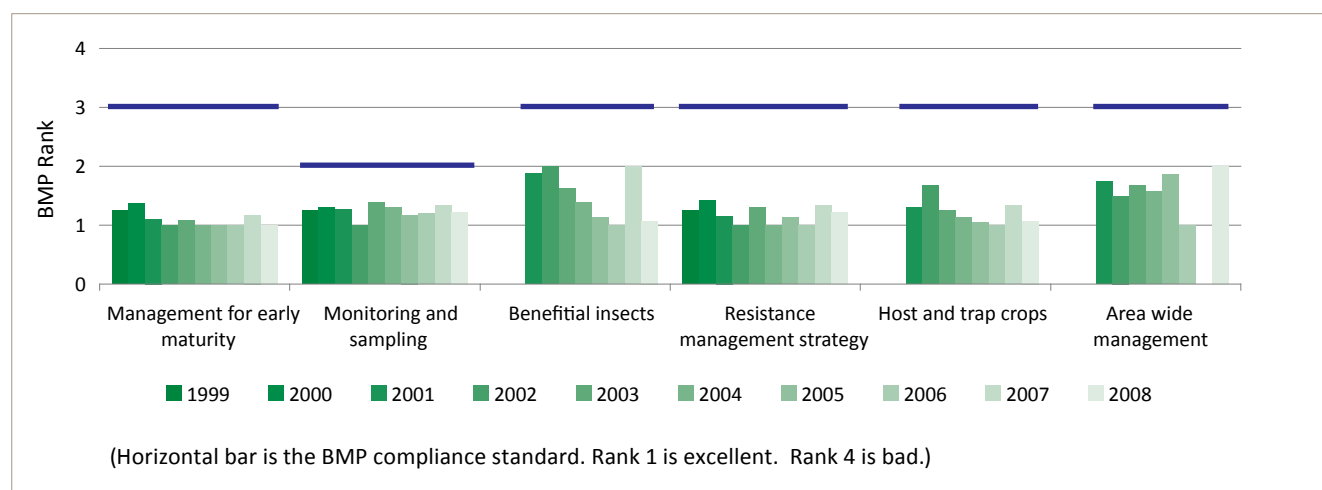


Figure 86 The mean BMP rankings for management for early maturity, monitoring and sampling, beneficial insects, resistance management strategy, host and trap crops and area wide management on BMP audited cotton farms over 10 years between 1999 and 2008



Farm design and management module

The design of a cotton farm plays an important role in minimizing off site movement of pesticides and nutrients. This module focuses on pesticide movement in soil sediments and water, but does include a reference to buffer zones to reduce aerial transport of pesticides from spray drift. Figure 87 shows the mean BMP ranking for farm design and management improved significantly by 46% from 2.42 in 1999 to 1.30 in 2008. Most of the improvement was between 1999 and 2006 (59%). There was a decline in the practice rankings in 2007 and 2008, which is attributed to the drought and subsequent capital and operational cost cuts. There has been a high standard of compliance in the last five years.

A breakdown of the mean BMP rankings for the 5 farm practice criteria in the farm design module is shown in Figure 88. The BMP certification standard is a rank 2 for all these objectives, except erosion and water control, which has a certification standard of 3.

Figure 88 shows a 56% improvement in erosion and water control, 46% improvement in management of storms and a 30% improvement in the use of buffer zones between 1999–2006. The main difference between a ranking of 2 and 1 for erosion control is increased use of stubble retention and minimum tillage. The main difference between a ranking of 2 and 1 for storm water management is improved documentation of procedures.

Two of these practices are specifically related to dryland cotton production where Figure 88 shows a 22% improvement in erosion and run off control between 1999 and 2008. The control and cleanup of runoff has improved slightly. There was a spike to a BMP ranking of 3 in 2002. The reason for this is not clear, possibly some new farms entering the program that had poor procedures.

The practice of using buffer zones improved between 1999 and 2008. The use of vegetative buffer zones is the main difference between a ranking of 2 and 1 for this practice.

Figure 87 The mean Cotton BMP audit rankings for the farm design practice criteria between 1999 and 2008

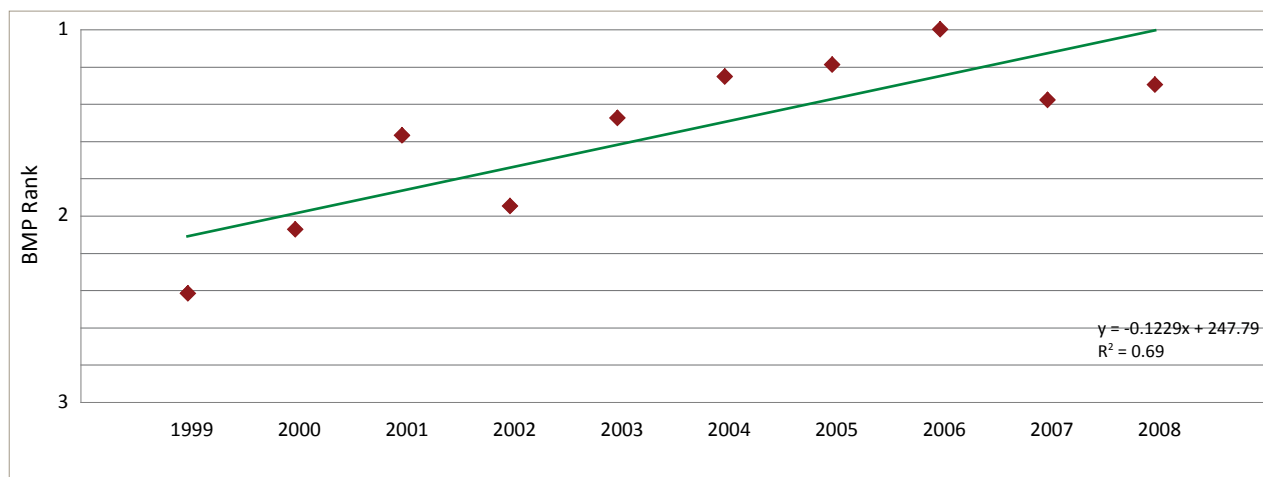
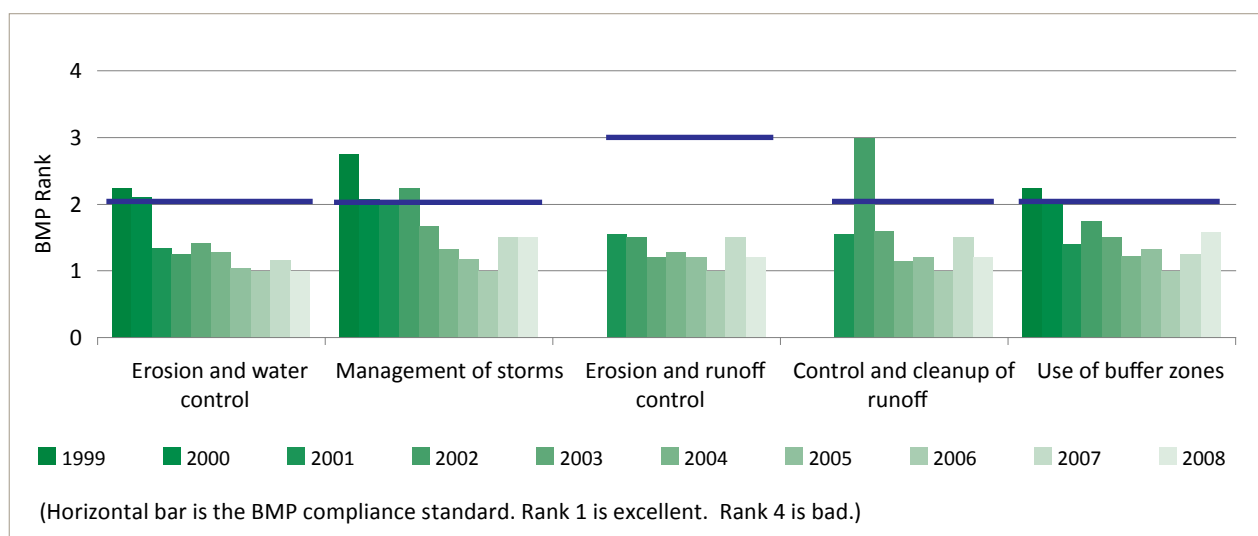


Figure 88 The mean BMP rankings for management for erosion and water control, management of storms, erosion and run off control, control and cleanup of runoff and use of buffer zones on BMP audited cotton farms over 10 years between 1999 and 2008



Farm hygiene module

Cotton is susceptible to the adverse effects of a number of crop diseases. When the second edition of the BMP manual was being compiled the cotton industry was very concerned about the recent discovery of fusarium wilt disease. Hence, the focus of this module is on this disease, with less emphasis on other diseases such as black root rot.

Figure 89 shows that the mean BMP farm practice ranking improved 39% from 1.99 in 2001 to 1.20 in 2005 for the 4 objectives that make up the farm hygiene module. There was a 24% improvement in the farm hygiene practices between 2001 and 2008. There was also a fall in the farm hygiene rankings in 2007 and 2008.

Figure 90 shows the data for each farm hygiene practice associated with this module. There were improvements in relation to the detection and notification of fusarium wilt up to 2006. Allen *et al* (2008) reported increased distribution and incidence of Fusarium wilt in recent years, which is also reflected in the poorer BMP rankings for 2007 and 2008.



Figure 89 The mean Cotton BMP audit rankings for all farm hygiene practice criteria between 1999 and 2008

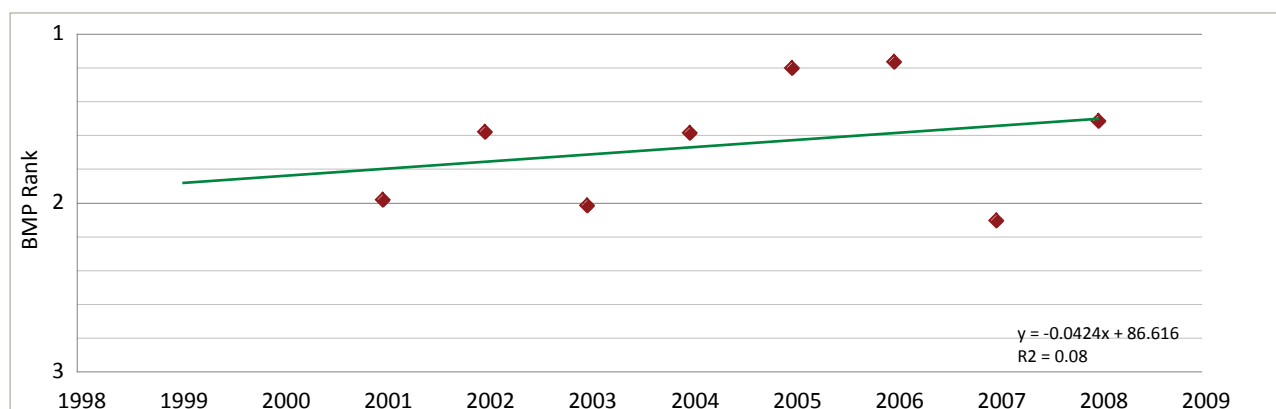
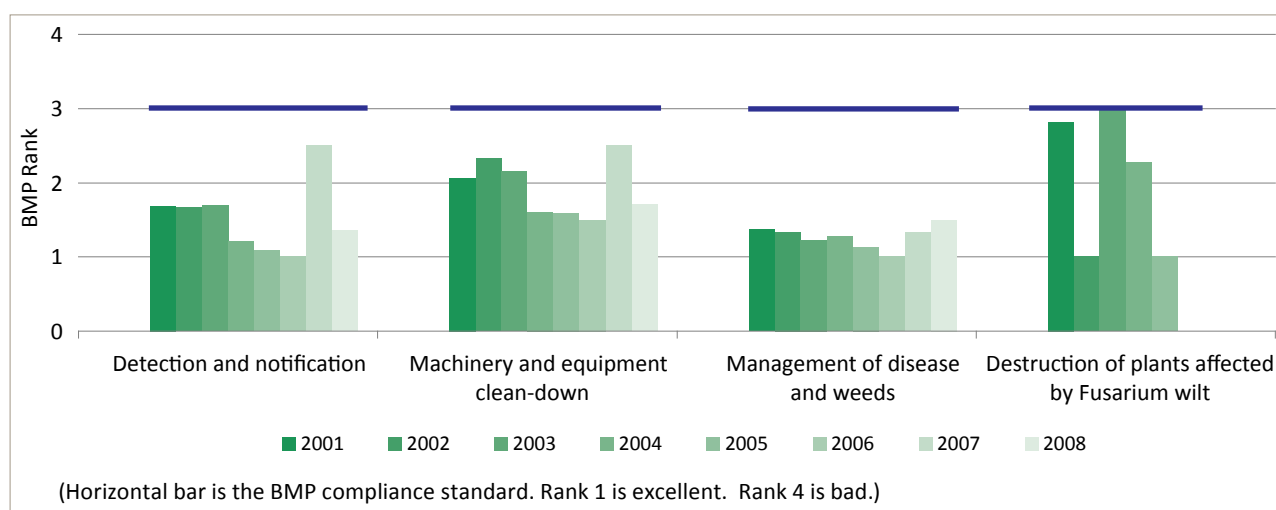


Figure 90 The mean BMP rankings for management for detection and notification of Fusarium wilt, machinery and equipment clean down, management of diseases and weeds and destruction of plants affected by Fusarium wilt on BMP audited cotton farms over 10 years between 1999 and 2008



The machinery and equipment clean down and management of the disease and weeds also improved between 2001 and 2008 and the increased BMP rankings in 2007 and 2008, again could be due to some cost cutting as a result of the drought. There is considerable fluctuation in the BMP rankings for the destruction of plants affected by *Fusarium* wilt. This reflects differences in individual circumstances of any disease outbreaks and the options available as a management response. For example if a grower has 10 infected plants their management response will be very different to a grower that has 10 hectares of infected plants. The Cotton CRC led a large campaign known as “Come clean go clean” and Allen *et al* (2008) have summarised how best to manage crop diseases.

PRE-CERTIFICATION AUDITS IN 2006

Pre-certification audits were introduced to the Cotton BMP program in 2006 as part of an impetus by Cotton Australia to increase the number of growers participating in the program.

As a result in 2006, 128 new growers entered the BMP program and completed a pre-certification audit. In 2007, 60 more growers entered the program. In 2008, a further 14 growers had a pre-certification audit completed on the new land and water modules, whilst six growers have had an audit on the petrochemical storage (as at 31 August 2008).

The BMP rankings of these 213 farms for these modules are presented in Figures 91–97.

The mean pre-certification audit BMP ranking for each BMP module is shown in Table 36.

The main trend in Table 36 is that the mean BMP ranking for certified audited farms was 1.38 which was 24% better rankings than mean BMP ranking for the pre-certified farms (1.82). The audited farms had equal or better BMP rankings when compared to the pre-certification audit farms for all the modules each year, except the IPM and farm hygiene module in 2007. Data for each BMP module is reported in the following sections.

Application of pesticides module

The BMP farm practice rankings for the application of pesticides modules for 2006 and 2007 is shown in Figure 91, on the following page. A comparison of the two years shows some of the practices were better, some were the same, and some are worse between the 2006 and 2007 farms. There is little point comparing the 2 years of data, and a clearer story may become evident in future years.

Storage and handling of pesticides module

The BMP farm practice rankings for the storage and handling of pesticides modules for 2006 and 2007 is shown in Figure 92, on the following page. Three of the practices (signage, emergency procedures and work procedures) are close to rank 3. These are three practices that are relatively easy to fix with little cost, although growers are somewhat skeptical of the value of having written procedures, especially on small farms with few staff. They view it as bureaucratic.

Integrated pest management module

The BMP farm practice rankings for the integrated pest management module for 2006 and 2007 is shown in Figure 93, on page 97. The practices were better on the 2007 farms than the 2006 farms. The main opportunities for improvement are related to the agronomy of crop checking and compliance with the resistance management strategy and the use of trap and host crops. Area wide management improvements will depend on the location of the farms and willingness of neighbours.

Farm design and management module

The BMP farm practice rankings for the farm design and management module for 2006 and 2007 is shown in Figure 94, on page 97. The BMP rankings are similar for both 2006 and 2007. The management of storms practice ranking could be improved with the development of a written storm water management plan. This is a common problem in farms that have not been audited.

Table 36 The mean pre-certification audit rankings 2006–2008 and the mean certification audit rankings for 2006 and 2007 of all the Cotton BMP modules

BMP MODULE	MEAN PRE-CERTIFICATION AUDIT RANKINGS				MEAN CERTIFICATION AUDIT RANKINGS		
	2006	2007	2008	Mean 2006–08	2006	2007	Mean 2006–2007
Pesticide application	1.85	1.77		1.81	1.24	1.73	1.49
Pesticide storage	2.10	1.86		1.98	1.2	1.49	1.35
IPM	1.60	1.35		1.48	1.03	1.43	1.23
Farm design	1.56	1.43		1.50	1.00	1.38	1.19
Farm hygiene	2.12	1.37		1.75	1.17	2.11	1.64
Petrochemical	2.63	2.40	1.74	2.26			
Land and water	1.94	1.55	1.93	1.81			
Average	1.97	1.68	1.84	1.82	1.13	1.63	1.38

Figure 91 Pre-certification audit rankings for the application of pesticides module in the Cotton BMP program, 2006 and 2007

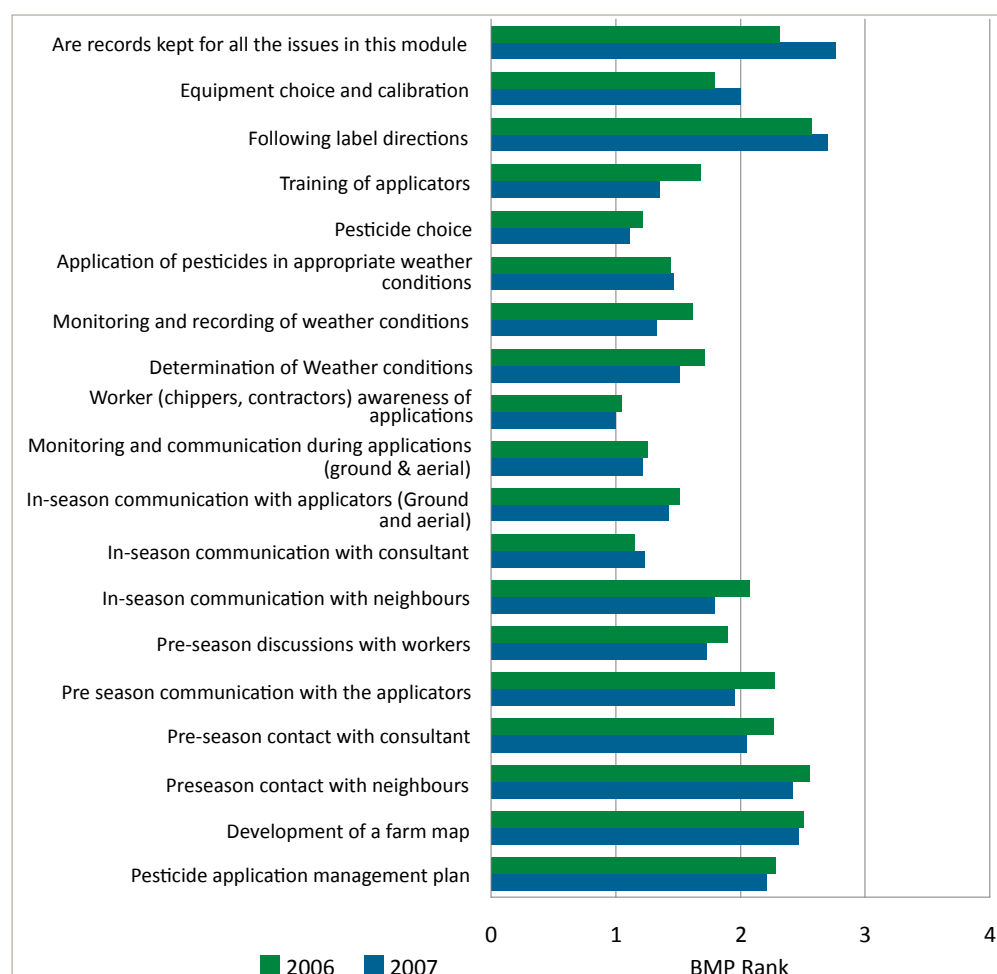


Figure 92 Pre-certification audit rankings for the storage and handling of pesticides module in the Cotton BMP program, 2006 and 2007

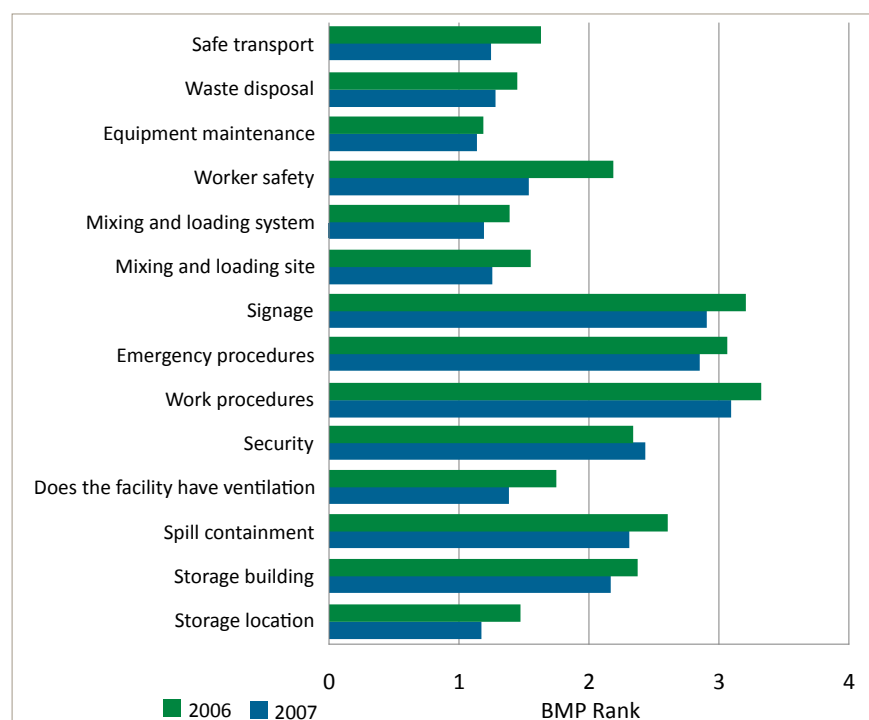


Figure 93 Pre-certification audit rankings for the integrated pest management module in the Cotton BMP program, 2006 and 2007

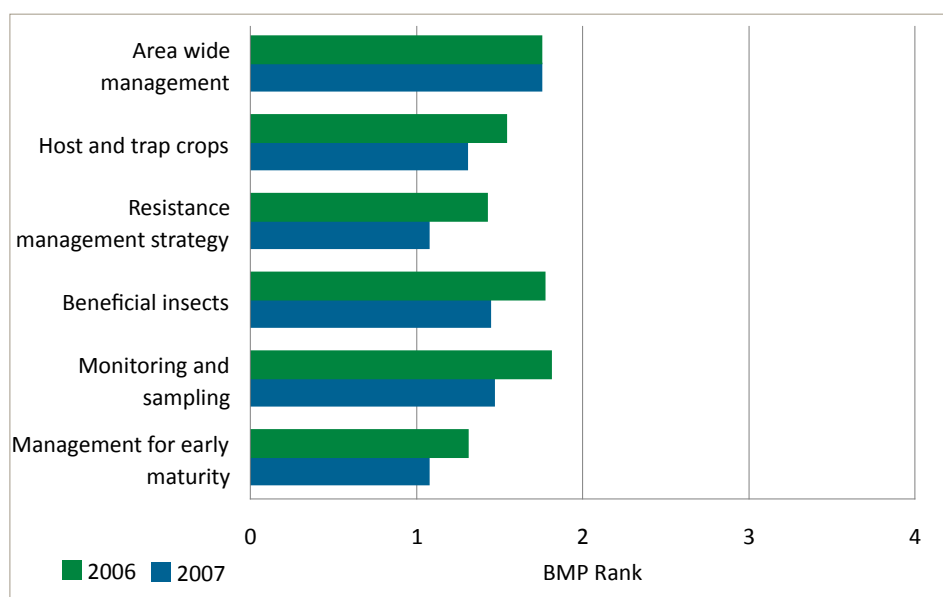


Figure 94 Pre-certification audit rankings for the farm design and management module in the Cotton BMP program, 2006 and 2007

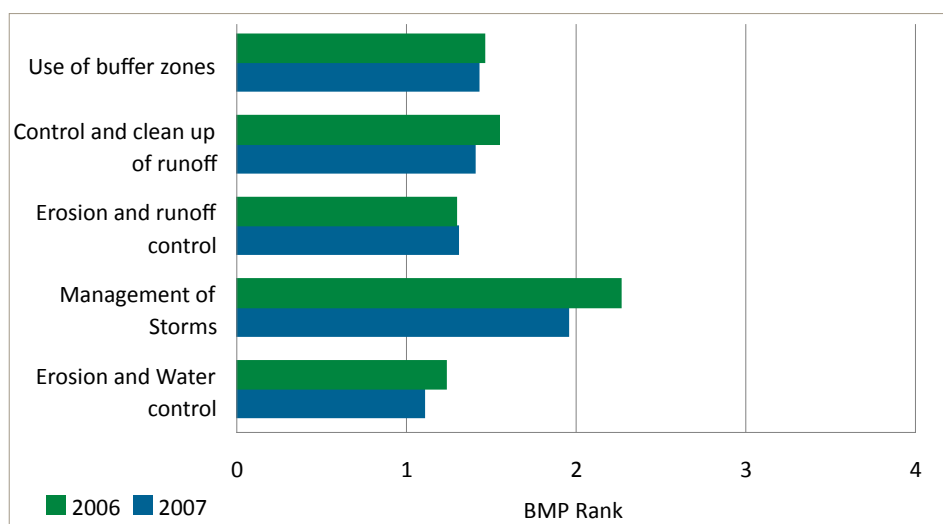
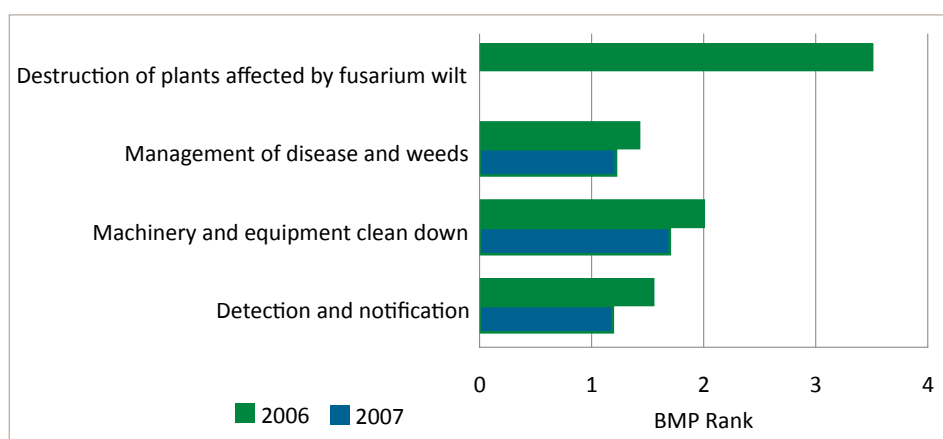


Figure 95 Pre-certification audit rankings for the farm hygiene module in the Cotton BMP program, 2006 and 2007



Farm hygiene module

The BMP farm practice rankings for the farm hygiene module for 2006 and 2007 is shown in Figure 95, on the previous page. No data was available for the detection of *Fusarium* wilt criteria in 2007 as the Cotton Australia field staff decided no longer to record this information. Allen *et al* (2008) reported increased distribution and incidence of *Fusarium* wilt in recent years, which is reflected in the high BMP ranking for 2006.

Petrochemical storage module

Figure 96 shows the BMP farm practice rankings for petrochemical storage on 79 cotton farms in 2006, in 2006, 60 cotton farms in 2007 and 6 farms in 2008. During the 3 years the practices of those farms joining the program have been better than those of the previous years. There appears to be some relatively easy opportunities for improvement in the three criteria related to emergency procedures, work procedures and signage. This is a similar finding to the pesticide handling and storage module. Waste disposal can now be done with oil recycling programs. Spill containment usually involves the installation of concrete or earth bunding and can be an expensive exercise for some farms.

Land and water module

Figure 97 shows the 25 BMP farm practice rankings for the land and water module on 79 cotton farms in 2006, 60 cotton farms in 2007 and 14 farms in 2008. Given the small sample size in 2008 it is not really possible to be definitive about any three year trends.

The riparian zone management rankings are on average closer to a rank 2 than a rank 1. A ranking of 2 means there is active management of the riparian zone. To obtain a ranking of one requires

attention to details such as replanting, active rehabilitation, and off stream watering points for stock.

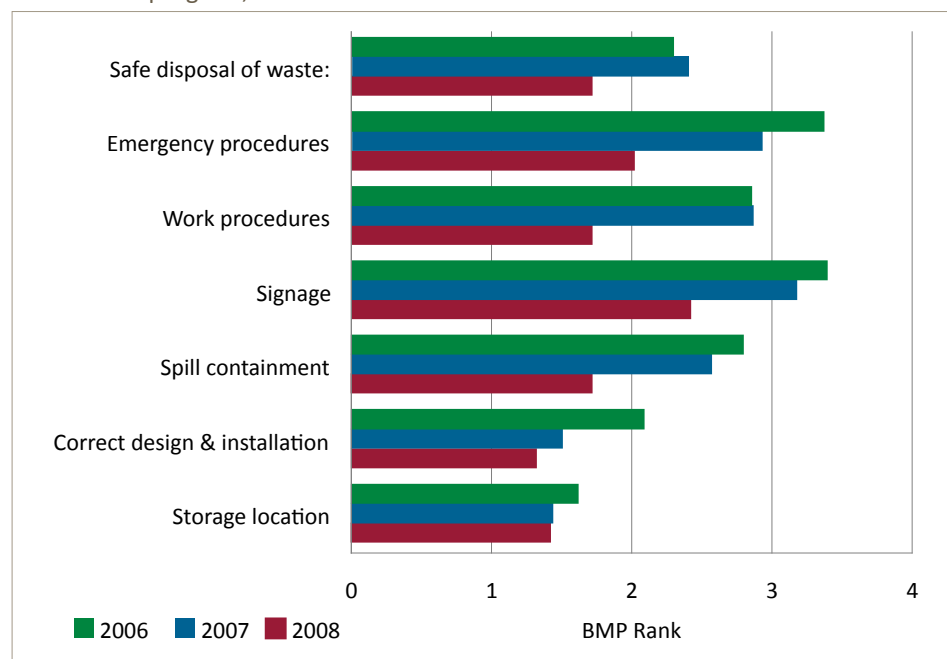
There are two objectives related to native vegetation have some of the highest rankings in the module. A ranking of 3 means that native vegetation is not marked on farm maps and is not managed. A ranking of 2 means there is some active management such as weed control, whilst a ranking of 1 requires a higher level of management including active involvement in local groups or with neighbours.

A series of the objectives are related to drip and centre pivot/lateral move irrigation systems. Less than 5% of growers have drip irrigation and about 10 % have centre pivots and lateral move systems, hence some of the gaps in that data set. There is a series of objectives related to furrow irrigation. To achieve a ranking of 1, growers need to be measuring and recording specific water use figures, have measured their soil properties, and have adopted that latest best practices to improve furrow irrigation. These are discussed in Chapter 4.

The soil management objectives collectively have the best rankings in Figure 97. To achieve a ranking of one growers need using soil tests, actively managing erosion and soil structure. A detailed discussion of soil management is found in Chapter 4.

A series of objectives are related to the farms resources and plans. To achieve a rank 1 detailed farm maps are required as well as environmental risk assessments. There is an opportunity for improvement in relation to these objectives.

Figure 96 Pre-certification audit rankings for the petrochemical storage module in the Cotton BMP program, 2006–2008



SUMMARY

The analysis of the Cotton BMP program farm practice audit criteria for the 10 years between 1999 and 2008 shows it is possible to identify and quantify how cotton growers have implemented changes to a wide range of their farm management practices.

The analysis showed there was a very high standard of legal compliance on farms between 1999–2008 where the BMP program has been adopted.

The mean BMP ranking for all 47 farm practice criteria from the pesticide application, pesticide storage, integrated pest management, farm design and farm hygiene modules for the 10 years

between 1999 and 2008 showed a 29% improvement, whilst it showed a 45% improvement between 1999 and 2006.

There was a fall in the mean BMP farm practice standards in 2007 and 2008 that is attributed to the drought. The drought meant that farms were less profitable and hence managers were forced to cut costs, especially those of a capital nature, to ensure the enterprise remained economically viable. Another related contributing factor to this fall in practice standards was that the cotton industry had less funding and staff to help growers with BMP implementation. Between 1999 and 2006 the BMP program had strong political and financial support from the cotton industry as well as the Australian Government. The ongoing drought

Figure 97 Pre-certification audit rankings for the land and water module in the Cotton BMP program, 2006–2008



eventually led to a decline in BMP interest during 2007. Between 2008 and 2009, the cotton industry recommitted itself politically to BMP and despite the drought, it was given higher priority than in the previous 2007 season. This could explain the improvement in the BMP rankings between 2007 and 2008.

These improvements in farm management practices were due to:

- A 7% improvement in the 19 pesticide application management practices between 1999 and 2008. Between 1999 and 2006 there was a 31% improvement in the mean BMP rankings. The main farm practice improvements were related to pre season communication with workers, in season communication between the grower and agronomist and chemical applicator, determination of weather conditions, monitoring and recording of the weather, and application of pesticides in appropriate conditions. There was a consistently high standard of record keeping, pesticide choice, worker awareness on BMP certified farms.
- There was a 45% improvement in the pesticide storage practices between 1999 and 2008. Between 1999 and 2006 this improvement was 56%. The major improvements were in spill containment, storage ventilation, security, work procedures, emergency procedures, signage, mixing and loading, worker safety, and waste disposal.
- The mean farm practice BMP ranking for the integrated pest management practices was consistently of a high standard and remained relatively constant compared to the other BMP modules. Between 1999 and 2006 IPM practices improved by 18%. In 2007 and 2008, IPM practices declined by 21% from their peak in 2006, again due to the drought and some cost cutting by growers and their agronomists. The major improvement was in the monitoring of beneficial insects.
- The mean farm practice BMP ranking for farm design and management improved 46% between 1999 and 2008. Most of the improvement was between 1999 and 2006 (59%) and the small decline in practice rankings in 2007 and 2008 was again due to the drought and subsequent capital cost cutting. The major improvements were in erosion and water control, management of storms, control and clean up of runoff and the use of buffer zones.
- The mean BMP farm practice ranking for the farm hygiene module improved 24% between 2001 and 2008. The major improvements were in detection and notification of Fusarium wilt, machinery and equipment clean down and destruction of plants affected by Fusarium wilt.

Pre-certification audits were introduced to the Cotton BMP program in 2006 as part of an impetus by Cotton Australia to increase the number of growers participating in the program. Between 2006 and 2008, 213 farms joined the BMP program. The analysis showed the mean BMP farm practice ranking for certified audited farms between 2006 and 2008 was 24% better than the pre-certified farms that has not been externally audited. This supports a personal observation that the extra rigour associated with external audit does lead to additional on-farm improvements in practice. It does however come at a cost and

this has been the discussed extensively by the cotton industry leadership.

The land and water module and petrochemical modules were introduced to the Cotton BMP program in 2006 and will require tracking for more seasons before any conclusions can be drawn about trends. However, an important improvement in the BMP program process is that these farm practice criteria have been captured and therefore can be monitored into the future.

Another important outcome of an industry wide examination of the BMP rankings is that it enables industry leaders to identify opportunities for industry wide improvement, which strategic campaigns can target. For example, some practices that the pre-certified audited farms could improve their practices include; record keeping, following label directions, pre season contact with neighbours, improved farm maps and pesticide application management plans, improved signage, emergency and work procedures associated with chemical storage and handling and development of stormwater management plans.

The aim of this project was not to determine if the BMP program itself has been the main driver of change. This could be done for some specific practices such as signage, but for others such as farm hygiene there is a complex interaction of activities undertaken by a range of individuals and organisations that have contributed to the improvements and was beyond the scope of this project. The BMP program does however offer a systematic process to monitor, track and report farm practice change.

A weakness in relying solely on the audit practice change data to quantify improvements is that some practices have had a "spring clean" just prior to the cotton grower formally entering the program. The means these improvements in farm practice as a result of "spring cleans" are not always captured.

For sustainability reporting areas where the BMP program can be improved include:

- The rewording of specific farm practice criteria to improve their clarity and purpose especially in the integrated pest management and farm hygiene modules
- Removal of duplication, especially in the land and water and farm design modules
- Inclusion of current issues such as greenhouse emissions, energy use, and improvements in the level of detail for soil, water and natural resource management practices
- Recording and tracking of the BMP farm practice criteria from the audits
- Publishing the aggregated data annually on the Cotton Australia web site
- Capturing the farm practice rankings as they are submitted to the BMP Program administrator.

Many of these improvements are currently being addressed by the cotton industry with the development of the new electronic 'on line' BMP (myBMP) planned for release in late 2009.

Sustainability reporting is the practice of measuring and disclosing economic, environmental and social performance. Sustainability reporting is now entering the main stream of business operations with the Global Reporting Initiative being the most widely used framework. The cotton industry is striving for the sustainable development and its key organisations include reference to it in their strategic plans. A number of economic, environmental and social indicators can be used to measure progress towards the sustainability goal. This review has identified many data already sets exist as well as some gaps and opportunities for improvement.

The modern Australian cotton industry is less than 50 years old. A wide range of strategies and technology are being implemented to ensure the modern Australian cotton industry doesn't suffer the same fate as past other international cotton industry failures. Monitoring key sustainability indicators is an essential strategy to ensure sustainable cotton production in Australia.

The project has:

- Reviewed the sustainability indicators literature;
- Identified, collected and compiled data to benchmark selected economic, environmental and social sustainability indicators for the Australian cotton industry including an analysis of its Best Management Practices program;
- Where possible, provided trend analysis;

The conclusions are presented in three parts: 1) Sustainability trends 2) Data availability and gaps and 3) Recommendations for the future.

SUSTAINABILITY TRENDS

Economic trends

The cotton production area in Australia expanded rapidly during the 1980s and 1990s and peaked in 2001 with a national gross value of production of \$1.9 billion. Since 2001, the production area of cotton has fallen in response the water shortages caused by drought. During the last 20 years, cotton yields have increased significantly, on average 32.9 kg/lint/ha/year and are the highest of any major cotton producing country in the world and are almost three times the world average. Australian cotton is now considered a premium quality product in the world, but still has some quality aspects to further improve. Cotton has traditionally been the most profitable crop where it is grown, producing a gross margin of \$500–\$1000 /ha. Costs are increasing and the net price received has been falling which for the last five years has averaged \$369/bale, which has meant that profitability of cotton has been falling. Cotton is a major source of regional economic activity where it is grown and usually generates 30–60% the gross value of all regional agricultural income where it is produced, which makes up 10–30% of the gross regional product. Its indirect impact on local economies is high. There is very good economic data available on the cotton industry, although it is not readily accessible for stakeholders. The major gap is employment data, which is not well quantified on farm, in the service industries and value chain.

Environmental trends

There have been significant improvements in the management of natural resources by the

cotton industry, particularly in the last decade. The analysis of the Cotton BMP program farm practice audit criteria for the 10 years between 1999 and 2008 shows it is possible to identify and quantify how cotton growers have implemented changes to a wide range of their farm management practices. The analysis showed there was a very high standard of legal compliance on farms between 1999–2008 where the BMP program was adopted. The mean BMP ranking for all 47 farm practice criteria from the pesticide application, pesticide storage, integrated pest management, farm design and farm hygiene modules for the 10 years between 1999 and 2008 showed a 29% improvement, whilst it showed a 45% improvement between 1999 and 2006. There was a fall in the mean BMP farm practice standards from 2006 standards in 2007 and 2008 that is attributed to the ongoing drought, which reduced expenditure, action and motivation. Despite the drought the BMP farm practice standards for the five years (2004–2008) were on average better than the previous five years (1999–2003). The analysis showed the mean BMP ranking for certified audited farms between 2006 and 2008 was 24% better than the pre-certified audited farms. This supports that the extra rigour associated with external audit does lead to additional on-farm improvements in practice.

There was a fall in the mean BMP farm practice standards from 2006 standards in 2007 and 2008 that is attributed to the ongoing drought, which reduced expenditure, action and motivation. Despite the drought the BMP farm practice standards for the five years (2004–2008) were on average better than the previous five years (1999–2003).

Key environmental indicators include soil, water, pesticide and transgenic crop trait stewardship, biodiversity and greenhouse emissions. There has been a reduction in soil tillage, widespread adoption of controlled traffic systems, the use of permanent bed farming systems, and less raking and burning of stubble. This has resulted in less soil compaction and improved soil physical structure. Nitrogen, phosphorus and potassium fertiliser rates are increasing in response rising yields and hence greater nutrient removal from farms. Higher fertiliser rates do not mean that high yields are unsustainable, however the sustainability of current nitrogen practices is questionable. The low soil carbon levels are another problem that needs to be improved. Soil testing is common for fertiliser decisions, but monitoring the long trends of soil tests is not done by the majority of cotton growers. The soil monitoring case study showed that these attributes can be monitored by farmers over long periods. Soil borne diseases such as fusarium wilt and black root rot have become significant problems in some areas and indicate the farming system is not sustainable unless improved management practices are adopted.

The availability of suitable irrigation water will remain the most limiting factor to cotton production in Australia. Total water extraction is limited by water sharing plans with which there is high compliance. There is strong evidence that growers have improved their water use efficiency by 3–4% per annum, or at

least 20% in last decade. There are many documented examples of even more significant improvements in one year by selected growers as a result of irrigation system improvements. However, more comprehensive data for the 2008 and 2009 cotton seasons is needed to be sure these individual improvements are taking place industry wide rather than just the early adopters of technology. The water quality where cotton has been grown is generally very good, with the exception of some specific and few in number groundwater bores. This could explain why there has been very little water quality monitoring on farms, which needs to be addressed.

Data on biodiversity for cotton farms is lacking. Whilst it is not the highest priority, an action plan and policy statement should be developed by the industry for biodiversity. It is recommended the cotton industry begin with simple achievable indicators, that can become more complex and aggregated over long time frames. Recommended biodiversity indicators include vegetation, birds, fish, mammals or insects species and farmers should pick one that interests them. Most biodiversity monitoring will require a degree of external expert input and this could be achieved through small projects funded by natural resource management agencies. Most (at least 70%) cotton farms have river or creek frontage and the status of the riparian land is another important indicator for the broader catchment sustainability.

Widespread adoption of transgenic cotton varieties has resulted in significantly less insecticide (82%) and herbicide (>80%) use. Growers have adopted this technology because of economic and environmental benefits, as well as social lifestyle benefits such as worker and family safety. Insecticide resistance is a major sustainability risk for the cotton industry. The management of insect resistance to transgenic cotton traits is the greatest potential immediate sustainability risk to the Australian cotton industry. Since the advent of Bollgard® cotton varieties, resistance to many conventional insecticides has declined. There have been no reports of field failures of the transgenic Bollgard II® varieties due to resistance, however recent data shows an increase in the frequency of *Cry2Ab* resistance alleles in *Helicoverpa punctigera*, which is being closely monitored.

The cotton industry has good data sets available from case studies and research reports for environmental indicators. However, these generally give a 'point in time' rather than a long term trend and are rarely industry wide and are often associated with the best producers, rather than the pro-verbal average. There are very few data sets that can be used to track changes over long periods of time. The BMP analysis showed it has great potential for monitoring long term trends, which could be supplemented with some targeted and repeated surveys as needed.

Social trends

Key social sustainability indicators include education levels, demographics, employment, health, community attitudes, social capital, research and development and compliance with the law.

The education qualification levels of the cotton industry are higher than other agricultural industries. Many training initiatives are underway in the cotton industry and participation rates

are between 20–80% industry participation depending on the course.

The cotton industry is one of the leading employers in communities where it is grown. The specific number of people employed by the cotton industry is not clear. The cotton industry generates many permanent and casual jobs, although labour demands are falling. It has traditionally provided some of the best salary packages in agriculture. It is also evident that 75% of cotton growers have been working more than 40 hours per week, which is considerably more than the national average. The drought has also significantly reduced employment in the cotton industry by 30–60%.

The number of cotton farmers has been falling and it is estimated there are now 800 cotton growers in Australia. Cotton farmers are younger than other farmers that do not grow cotton. Forty percent (40%) of cotton growers are aged under 35 years old, compared to 26% of other farmers. Most of cotton agronomy consultants were aged between 35 and 49 (65%). Health is improving. Deaths rates in the cotton industry are very low. Workers compensation claims for accidents have been falling, but so too has the planted cotton area. This will need to be monitored as the planted cotton area increases with expected forecasts. There is evidence of significantly improved occupational health and safety practices. The number of complaints received by the NSW EPA has fallen from around 50 per year in 2001 to 3 per year for 2006 and 2007, which indicates there is less anxiety in the community towards cotton production.

People in cotton communities held a positive opinion of the cotton industry. Most people outside the cotton industry have a negative attitude towards the cotton industry and their main concerns were water allocations and pesticide usage. Independent attitudinal research into the cotton industry shows that chemical use, spray drift and high water use concerns had reduced significantly between 1998 and 2004 in cotton communities and regional towns.

The cotton industry has very high levels of social capital and consists of many well supported organisations and networks. There is rising participation in the cotton industry by women.

The cotton industry has a very strong culture and has been a long term investor in research and development. The responsibility of growers in terms of environmental compliance and any breaches of environmental laws is high, but specific data are not readily available from Government agencies. This is partly because Government does not segment farmers by the commodities they produce.

DATA AVAILABILITY AND GAPS

The cotton industry does have some excellent sources of information. There are hundreds of research reports and thousands of scientific papers. The industry has held 14 national conferences, which include conference papers. The stories in The Australian Cottongrower magazine contain about a 30 year repository of information and events. The cotton industry also has several well populated internet sites containing reports and discussion on a variety of current topics.

There is a vast amount of information that is available for a 'point in time'. However, there are very few data sets that can be easily used to monitor changes over time, especially longer term trends across the industry. In particular, there is a shortage of data for many of the environmental indicators. Tables 37–39 summarise important economic, environmental and social sustainability indicators for cotton industry and their relative ease of collection and current information quality.

Economic data

Most economic data is easy to collect and there is excellent economic data including trends over time, although it is not readily accessible on cotton industry internet sites. Information at the local government scale is lacking, but in most cases would match the regional scale. There is a gap in the profitability figures of farm business such as return on equity and interest coverage, which are sometimes requested by stakeholders. This information is difficult to collect due to private business (wealth) sensitivities, and government surveys do not segment the cotton industry figures as opposed to larger industries such as grain and beef cattle.

Environmental data

Environmental data is patchy. There are some excellent data sets available from case studies, research reports and the two industry environmental audits. However, these generally provide a 'point in time' story rather than a long term trend and are rarely industry wide. For case studies, the information is usually about the best producers rather than the "pro-verbal" average producer.

There is data over a reasonable timeframe for fertiliser rates, disease levels, river water quality, pest (weeds and insects) density and distribution and their resistance levels to various chemistries to manage them. Notable environmental data gaps include soils (physical, chemical and biological status), water use and efficiency, ground water quality, biodiversity, and greenhouse emissions/carbon balances.

A key issue for the cotton industry is understanding river health and environmental flows. This knowledge is linked to water sharing plans and monitoring outcomes related to these plans. Improved monitoring of river health is needed and will need to be resourced by Government. Once this data is available it will be up to the cotton industry to account for its impacts.

Social data

There was reasonable data relating to social indicators for university level training, demographic data (age, gender), hours worked, accidents, community attitudes, cotton industry social capital, research and development, and formal community complaints related to industry activities. This was an unexpected finding as the gathering of social data is usually considered difficult for sustainability reporting.

Gaps in the social data included employment data, which is arguably an economic indicator, vocational training and other non degree capacity building measures such as apprenticeships, number of deaths, measures of social capital related with other local industries such as grain production, bee keeping, cattle

or fruit production. Another notable gap for social responsibility and environmental management is data related to compliance with legislation related to natural resource management. Government agencies do not provide this information and it is unlikely they will into the foreseeable future.

Tables showing summaries of economic, environmental and social sustainability indicators for the cotton industry begin on the following page.

Table 37 A summary of economic sustainability indicators for the cotton industry

(Key: ↓/● falling/bad, ↑/● rising/good, –/● no trend/ OK , ●●● easy/high → ○○○ difficult/low)

ECONOMIC FUNCTION	ECONOMIC INDICATOR	CURRENT TREND OF INDICATOR	EASE OF COLLECTION	CURRENT INFORMATION QUALITY	PRIORITY	COMMENT
Cotton industry	Planted area (ha)	↓ ●	●●●	●●●	●●●	The area has been declining, but increased areas are forecast in 2009–10.
	Yield (bales/ ha)	↑ ●	●●●	●●●	●●●	Very high yields by world standards and rising.
	Quality	↑ ●	●●●	●●●	●●●	Improving quality. Quality reporting should be segmented into the main parameters (length, strength, micronaire, grade). Aust. cotton shippers have good information.
	Bales produced	↓ ●	●●●	●●●	●●○	Beginning to rise again with possible recovery from drought and increased yields.
	Grower numbers	↓ ●	●●●	●●●	●●○	Grower numbers are falling and is of interest to industry. Employment figures are a higher priority indicator for community.
	Cotton price per bale	– ●	●●●	●●●	●●○	Price is very volatile (daily). It is a function of currency rate and physical price. Price is captured in gross margins.
	Cotton seed price	– ●	●●●	●●●	●○○	High price due to drought. Price is in gross margins.
Gross value	Gross value (\$) (industry scale)	↓ ●	●●●	●●●	●●●	Falling gross value, but beginning to rise again with possible recovery from drought.
	Gross value (regional scale)	↓ ●	●●●	●●○	●○○	Falling gross value, but beginning to rise again with possible recovery from drought.
	Gross value (local government regions)	↓ ●	●○○	●○○	●●○	Harder to collect than at the industry and regional scale, but local government is a key stakeholder for communities. Some local government regions are trending better than others.
Economic returns	Income / ha	– ●	●●●	●●●	●●○	Strongly influenced by yield and price.
	Costs / ha	↑ ●	●●●	●●●	●●○	Costs are rising and good segmented data is available.
	Gross margin/ha	↓ ●	●●●	●●●	●●●	Falling gross margins due to rising cost and falling price.
	Profit/ha	↓ ●	●●●	●●●	●●○	Falling profit.
	Return on investment (%)	↓ ●	○○○	○○○	○○○	Very little data. Difficult to collect due to private wealth sensitivities. Government surveys do not segment the cotton farmers from beef, grain, sheep etc.
	Equity / interest cover	↓ ●	○○○	○○○	○○○	As above.

Table 38 A summary of environmental sustainability indicators for the cotton industry

(Key: ↓/● falling/bad, ↑/● rising/good, –/● no trend/ OK, ●●● easy/high → ○○○ difficult/low)

ENVIRONMENTAL FUNCTION	ENVIRONMENTAL INDICATOR	CURRENT TREND FOR INDICATOR		EASE OF COLLECTION	CURRENT INFORMATION QUALITY	PRIORITY	COMMENT
Soil structure	Plant available water (soil moisture deficit)	↑	●	●○○	●○○	●●○	Improved soil structure, but data difficult to collect.
	SOILpak score	?	●	○○○	○○○	○○○	Subjective indicator. Not calculated by agronomists.
	Soil erosion	?	●	○○○	○○○	●○○	Very little data on erosion. There is information on management practices related to erosion. Eg BMP.
Soil fertility	Organic carbon %	↓	●	●●○	●○○	●●●	Decreasing and low levels. No industry wide data, although some good case studies.
	Soil phosphorus	–	●	●●○	●○○	●●○	Fertiliser replacement increasing. No industry wide data, although some good case studies.
	Soil potassium and other cations	–	●	●●○	●○○	●●○	Fertiliser replacement increasing for potassium (K). No industry wide data, although some good case studies.
	Fertiliser rates (N, P, K)	↑	●	●●●	●●●	●●○	Fertiliser use increasing. Good industry wide data.
Soil salinity and sodicity	EC, Sodium, Chloride, ESP%	–	●	●●○	●●○	●●●	Soil salinity is generally low, soil sodicity high (sub soils) , no trend. Reasonable data available.
	Pesticide residues in soils	↓	●	○○○	●○○	●○○	Falling. Small data sets available in published papers.
Soil disease levels	Disease levels of major cotton diseases	↑	●	●●○	●●●	●●●	Trend was increasing for some diseases in 2007–08. Good data available.
Total water use by industry	ML	↓		●●○	●●○	●●●	Falling due to drought. Industry wide data not collected. Each grower has their own records.
	Compliance with law – Breaches of water legislation	?	●	●○○	●●○	●●○	Data is not available.
	Trades – Number and volume	?	●	●○○	●○○	●○○	Increased trading of water, data quality is rapidly improving.
Water use efficiency on farm	Crop WUI	↑	●	●○○	●●○	●○○	Improving. This index is usually used in research only.
	Gross Production WUI	↑	●	●○○	●○○	●●●	Improving. Need for 07–08 & 08–09 data.
	Irrigation WUI	↑	●	●●○	●●○	●●○	Improving. Need for 07–08 & 08–09 data.
	Whole Farm irrigation efficiency	↑	●	●○○	●○○	●●○	Improving. Need for 07–08 & 08–09 data.

Table 38 continued

ENVIRONMENTAL FUNCTION	ENVIRONMENTAL INDICATOR	CURRENT TREND FOR INDICATOR		EASE OF COLLECTION	CURRENT INFORMATION QUALITY	PRIORITY	COMMENT
Groundwater levels	Rising or falling	↓	●	●●○	●●○	●●●	Levels falling in most areas. Data is in most water sharing plans and monitored by agencies.
Irrigation scheduling	Method used for scheduling	↑	●	●●●	●●●	●●○	Increasing and high adoption of technology.
Water quality	Groundwater	–	●	●○○	●○○	●●●	Little data and varies from site to site.
	Surface water	–	●	●○○	●●●	●●●	Water quality is improving . Excellent data sets.
Biodiversity	Area of land cleared last 10 years (ha)	?	●	●○○	●○○	●●○	Trend of less and little clearing. Unclear data but no records.
	Breaches of land clearing regulations	?		●○○	○○○	●●○	No records.
	% of farm managed as native vegetation	–	●	●●○	●●○	●●○	Some survey data, which could be easily improved.
	Vegetation quality index	?	●	○○○	○○○	●○○	Need improved data.
	Bird species and numbers	–	●	●○○	●●○	●●○	Some scientific studies, but other studies needed in some regions. Birds Australia volunteers can do the monitoring.
	Fish species and numbers	?	●	○○○	●○○	●●○	Need improved data. Source State DPIs (fisheries)
	Insect species and numbers	?	●	●○○	●●○	●●○	Many research studies that need reviewing by an expert entomologist.
Riparian land management	Changes in riparian vegetation and landform condition	?	●	●○○	●○○	●●○	Some baseline data held by Murray Darling Authority
Weeds	Density and distribution	↓	●	●○○	●●●	●●●	Falling weed density and distribution. Varies with species.
	Herbicide resistance levels	–	●	●●○	●●●	●●●	Low resistance. Research studies published.
Pests (insects)	Density and distribution on insect pests	–	●	●●●	●●●	●●●	Highly variable with season and species dependent. Could segment species data. Research studies published.
	Level of resistance to key insecticides by pest species	↓	●	●●●	●●●	●●●	Falling resistance to most insecticide chemistry.

Table 38 continued

ENVIRONMENTAL FUNCTION	ENVIRONMENTAL INDICATOR	CURRENT TREND FOR INDICATOR		EASE OF COLLECTION	CURRENT INFORMATION QUALITY	PRIORITY	COMMENT
Chemical use	Herbicide use	↓	●	●●●	●●●	●●●	Increasing glyphosate use, but decreasing use of other more toxic herbicides.
	Total pesticide risk load	↓	●	●○○	●○○	●●○	Total pesticide usage weighted by environmental risk. Can be calculated by experts.
	Insecticide use	↓	●	●●●	●●●	●●●	Decreasing use.
	Compliance with resistance management plans. (%)	–	●	●●○	●●○	●●●	High compliance.
Transgenic crop trait stewardship	Resistance trends	↑	●	●●○	●●●	●●●	Possible increasing trend, which is under close scrutiny.
	Compliance with management plans	–	●	●●○	●●○	●●●	High but no published data
Greenhouse emissions and energy	Nitrous oxide and CO2 emissions	?	●	●○○	●○○	●●●	Very little data other than a few case studies. Techniques to calculate not fully developed.
	Energy use	?	●	●●○	●○○	●●●	Could look at renewable and non renewable energy use in the future
Farm practices	Crop rotations	↑		●●●	●●●	●●○	Trend of longer rotations with grain crops, some of which caused by drought. Good data.

Table 39 A summary of social sustainability indicators for the cotton industry

(Key: ↓/● falling/bad, ↑/● rising/good, –/● no trend/ OK , ●●● easy/high → ○○○ difficult/low)

FUNCTION	INDICATOR	CURRENT TREND OF INDUSTRY FOR THE INDICATOR		EASE OF COLLECTION	CURRENT INFORMATION QUALITY	PRIORITY	COMMENT
Education	Highest post school qualification of cotton growers	↑	●	●●●	●●●	●●●	High and improving qualifications for agricultural industries. Data is in census classifications.
	Highest post school qualification of service industry	↑	●	●●○	●●○	●●●	High and improving qualifications. Non census classification thus requires industry survey. Service industry is not necessarily specific to cotton.
	Highest post school qualification of cotton ginners	↑	●	●●●	●●●	●●●	Improving qualifications. Data is in census classifications.
	Vocational training of farm staff (& service industries)	↑	●	●●○	●○○	●●○	A lot of industry training, but improved data analysis is required.
	Apprenticeships of farm staff	?	●	●○○	●○○	●●○	No data.
Employment	Number of people employed on farms	↓	●	●●○	●○○	●●●	Data is not available, but falling due to drought, technology improvements and OH&S risks.
	Number of people employed (industry)	↓	●	●○○	●○○	●●●	Falling due to drought. Improved data required.
	Number of people employed (indirectly)	↓	●	●○○	●○○	●●●	Falling due to drought. Improved data required.
	Income per week	–	●	●●●	●●●	●○○	High for agriculture. Question the census data as high number of self employed people.
	Hours worked	↓	●	●●●	●●●	●○○	Slight trend of falling, well above national average.
Health	Deaths on farms and cotton gins	↓	●	●●●	●○○	●●●	Very low death rates.
	Accidents / injuries / Workers compensation claims	↓	●	●●○	●●○	●●●	Falling trend. However needs monitoring as crop area increases.
Demographics	Grower age	–	●	●●●	●●●	●●○	Younger compared to the balance of agriculture.
	Gender participation in industry	–	●	●●●	●●○	●●○	For agriculture, reasonable gender balance in organisations. More males working on farms.
	Aboriginal participation in industry	–	●	●○○	●●○	●●○	Need better data, trend of less manual work such as cotton chipping, more traineeships being offered.

Table 39 continued

FUNCTION	INDICATOR	CURRENT TREND OF INDUSTRY FOR THE INDICATOR		EASE OF COLLECTION	CURRENT INFORMATION QUALITY	PRIORITY	COMMENT
Attitudes	Local community attitudes	↑	●	●●●	●●●	●●●	Strong and improved local support for industry
	Non local community attitudes	–	●	●●●	●●●	●●●	Mixed attitudes, mostly negative towards industry
	Industry attitudes	–	●	●●●	●●●	●●●	There are high levels of social capital
Social capital	Memberships of ACIC	–	●	●●●	●●●	●●○	There is strong industry social capital
	CCA memberships	↓	●	●●●	●●●	●●○	There is strong industry social capital
	WinCott memberships	↑	●	●●●	●●●	●●○	There is strong industry social capital
	Conference delegates	–	●	●●●	●●●	●●○	There is strong industry social capital
	Internet usage	↑	●	●●●	●●●	●●○	High and rising usage
	Other local cotton industry interactions with other industries such as beef cattle etc	–	●	●○○	●○○	●●○	No data, but scope to strengthen linkages with other industries and organisations.
Research & Development	Investment levels (culture and impacts)	↓	●	●●●	●●●	●●●	Investment has been falling due to drought. There is a very strong culture of R&D and its adoption.
Legal compliance & responsibility	Complaints received by regulatory authorities about cotton industry	↓	●	●●○	●●●	●●●	Number of complaints about industry practice is falling
	Fines imposed on cotton growers for natural resource management breaches	?	●	○○○	●○○	●●○	No data.

RECOMMENDATIONS FOR SUSTAINABILITY REPORTING IN THE COTTON INDUSTRY

Economic, environmental and social aspects of sustainability are interrelated. There is a need to be pragmatic and get started rather than continually trying to define the perfect set of indicators. Ideally, it should be done in conjunction with other activities and commodities that make up the farm and regional business and careful consideration needs to be given to attribution of cause and effect. Sustainable development is a journey and reporting changes can and should be implemented as issues evolve. As data accumulates over time, a clearer picture will emerge, priorities will change and opportunities and gaps can be filled. The ultimate goal is to report and monitor industry sustainability over the long term; decades, rather than a decade.

1. The cotton industry develops a five year sustainability reporting plan.

This will enable efficient allocation of resources and optimisation of industry and national data sets. It is not necessary to collect data on every issue each year. For example, issues such as some of the social data could be monitored in conjunction with the census every five years. Other environmental indicators such as biodiversity do not require annual monitoring. The use of long term reference sites, case studies and performance stories could be alternative sources of information where it is not practical to collect data for the entire industry. The plan needs to include data management. The internet could act as the repository as it is easy to access, search and update.

2. The cotton industry develop a sustainability monitoring and reporting process that includes at a minimum the following indicators (Tables 37–39 contain further details):

- i profitability (gross margin);
- ii economy (gross value of production and employment);
- iii water use ;
- iv water quality ;
- v pesticide use and technology stewardship (transgenic traits, chemistry resistance);
- vi soil quality;
- vii energy, greenhouse and carbon balance;
- viii regional biodiversity;
- ix industry demographics;
- x community attitudes and
- xi workplace health and safety.

3. The Cotton BMP farm practice rankings be used to monitor sustainability trends.

This will require some rewording of specific farm practice criteria to improve their clarity and will be enhanced with the inclusion of new modules which are currently under development. The aggregated data should be published annually on the Cotton Australia internet site. The proposed web based BMP system offers great potential to streamline this monitoring and reporting. It needs to be done without

creating extra work for growers and it is likely the feedback information will provide additional value to growers who are in the BMP program. Some annual or biannual survey supplementation could fill any knowledge gaps.

4. Cotton Australia establishes a formal stakeholder consultation roundtable that convenes annually to discuss sustainability matters.

Stakeholder engagement is a fundamental principle of sustainability reporting. It is important to include a broad and strategic group of stakeholders, set clear goals and objectives, focus on key issues and be realistic with ways to move forward. Stakeholder mapping would facilitate the makeup of the group. It will improve transparency, increase trust, lead to more meaningful dialogue and create the discipline for regular dialogue. It would also serve as a risk assessment process. Reporting the performance of issues that are important to stakeholders is more important than reporting things that are easy to measure.

5. The cotton industry undertake scenario planning activities to explore key drivers of change.

Done well, scenarios are a medium through which great change can be envisaged and be actualized. Scenarios are not predictions, but thought provoking and plausible stories about multiple ways the future may play out. Scenarios explore issues such as climate change, energy, technology, human capital, rural communities, food and fibre needs, environment, infrastructure, markets and governance. They provide a non threatening forum to discuss key issues. A discussion around a life cycle assessment of cotton production could enhance this discussion.

6. Cotton Australia produce a social responsibility statement for the cotton industry.

This would cover topics such as local communities, governance, human rights, OH&S, labour conditions and awards, gender, grievance and complaints procedures. This should cover the entire value chain as globally labour conditions in the manufacturing sector is a key issue for human rights organisations and many buyers of cotton products. A policy statement further strengthens Australia's position in a global context about important social issues related to human rights in the workforce.

7. The cotton industry formally approach the Queensland and NSW Government agencies to establish what environmental data they may be able to provide and their monitoring intentions for the future.

It may be possible to obtain funding for some baseline monitoring. This will also provide some independent assessment. An example, would be for biodiversity such as vegetation quality, fish or bird monitoring. It is recommended that environmental indicators are monitored at a catchment or regional scale.

8. Employment figures need to be better quantified both on farm, in the service industries and the value chain.

Regional multipliers and the economic linkages need greater analysis. This needs to include the direct and indirect impacts of cotton production and location of these activities. This needs to include greater analysis of potential drivers such as water scarcity, climate change, technology and modelling of different response scenarios.

9. **The Global Reporting Initiative should produce a specific sector supplement for agriculture at the industry level for a region/country.**

The Global Reporting Initiative is emerging as the international standard for sustainability reporting. It is unlikely the millions of individual farmers around the world will file sustainability reports; however, collectively as the farming industries, they do have stewardship of a large portion of the world's soils and freshwater resources.

Some more specific recommendations include:

Economic

1. **Cotton Australia make available on their internet site time series data related to key economic indicators.**

Many of these were surprisingly difficult to obtain over a period time (cotton areas, grower numbers, production figures, yields). This would require a small amount of resources to keep them up to date each year, possibly in a spreadsheet format.

2. **Increased analysis of cotton related economic activity in each specific local government areas from the census and other sources such as business surveys, which can be done more frequently.**

Many regional development programs are based on local government areas. This will require a programmed investment and ideally done in partnership with other key industries such as grain and livestock. An improved understanding of the economic flows in the community is also required. Some of this research is currently underway, but its attribution to cotton is not always clear.

3. **Financial figures such as return on capital, interest coverage on debt have been requested from certain stakeholders.**

It needs to be established if this is a critical need or are they being stickybeaks. These figures will always be difficult to obtain at an industry scale due to their confidentiality and number of other factors linked to their calculation such as company structures, other income, income tax, and borrowings. It may be possible every five years to commission a specific study, perhaps in partnerships with the major banks / accountants / ABARE to gather a snapshot. Discussions should also be held with ABS/ABARE who are increasing their surveys of irrigators due to the national water initiative. Other less sensitive financial figures such as gross margins could be obtained through the new electronic BMP system.

Environmental

1. **Encourage more cotton growers to compile their soil records over time such as the case study in this project.**

It will be necessary for industry leadership to assist this by initiating at least 10 case studies.

2. **Improve reporting of water use and water use efficiency indices (especially gross water use production index) at an industry level.**

There are some R&D projects currently underway that will enhance this information.

3. **Improve water quality monitoring on-farm, especially in relation to ground water.**

Some benchmarking programs should be initiated with regional catchment bodies.

4. **Develop an action plan to increase on-farm biodiversity data over a five year period.**

Regional catchment bodies should have some funding or other government initiatives. The Cotton Australia should also strengthen its action plan and policy statements in relation to maintenance or enhancement of biodiversity.

5. **Riparian land management and health can be monitored through the BMP scores.**

Encourage landholders to take some photographs for their own records as a reference point.

6. **Energy efficiency and greenhouse reporting tools need to be further developed.**

This should include greenhouse emissions, carbon balance and energy use. Cotton Australia should publish a climate change mitigation and adaptation policy.

Social

1. **For educational qualifications it is recommended that data be drawn from census data and for the cotton service industry, monitoring of CCA membership be used as a starting point.**

The census data can be analysed for reports on the "highest qualifications of growers and ginnery" but this cannot be done for cotton agronomists and others in the service sectors. Some of the 2006 Census data was not available when the data was sought for this project. It would be possible to purchase that data now.

2. **Improve vocational training and apprenticeships records of people working in the industry**

— rather than monitoring those that have completed courses and may no longer be working in the industry.

3. **Improved health trend data (deaths, accidents, workers compensation claims, days lost with injury,) could be collected from growers during annual surveys or new web based BMP system.**

Information on chemical complaints should be discussed with state authorities in Queensland and NSW each year.

4. The demographic data could be further developed for each community or local government area.

More detailed information from the cotton growing / ginning categories could be drilled out of the census for each region than what has been compiled in this report. This could be supplemented with local surveys to obtain information not covered in the census. This should be tracked over time, which is currently every five years for the census.

5. The annual reports of CRDC and the Cotton CRC are good repositories of R&D information and should form the basis of any reporting on R&D.

There is no need to duplicate this activity.

6. Information needs to be gathered on legal compliance related to water, vegetation and land clearing.

This could be done in annual surveys or sourced from the Government

BMP Program

For sustainability reporting **areas where the BMP program can be improved include:**

1. The rewording of specific farm practice criteria to improve their clarity and purpose, especially in the integrated pest management and farm hygiene modules
2. Removal of duplication, especially in the land and water and farm design modules
3. Inclusion of current issues such as greenhouse emissions, energy use, bio-security, and improvements in the level of detail for soil, water and natural resources
4. Recording and tracking of the BMP farm practice criteria from the audits
5. Publishing the aggregated data annually on the Cotton Australia web site
6. Capturing the farm practice rankings as they are submitted to the BMP administrator.

Many of these improvements are being addressed in the new electronic BMP version planned for release in mid 2009.

- Allen S (2008) Current and future trends – A disease update, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 6 pp.
- Allen Consulting Group (2002) Triple bottom line, Measurement and reporting in Australia, Making it tangible, Prime Ministers Community Business Partnership, Commonwealth of Australia, 116 pp.
- Anthony D (2004) Research and development opportunities, *Proceedings of 12th Australian Cotton Conference, 10–12 August 2004, Broadbeach, Queensland*, pp 39–56.
- Australian Bureau Agricultural and Resource Economics (2005) Signposts for Australian agriculture: A framework for developing economic and social indicators, National Land and Water Resources Audit, Australian Government, Canberra, 14 pp.
- Australian Bureau Agricultural and Resource Economics (2008) Australian commodity statistics December 2008, Australian Bureau Agricultural and Resource Economics, Australian Government, Canberra.
- Australian Bureau of Statistics (2006) Characteristics of Australia's irrigated farms 2000–01 – 2003–04, Australian Bureau of Statistics, Canberra, Publication 4623.
- Australian Bureau of Statistics (2007) Water and the Murray Darling Basin. A statistical profile 2000–01 – 2005–06, Australian Bureau of Statistics, Canberra, Publication 4610.055.007.
- Australian Cotton Cooperative Research Centre (2002) WEEDpak. A guide for integrated weed management of cotton, Australian Cotton Cooperative Research Centre, Narrabri, Australia.
- Australian Cotton Cooperative Research Centre (2005) Australian Cotton Cooperative Research Centre final report 1999–2005, Australian Cotton Cooperative Research Centre, Narrabri, Australia.
- Australian Cotton Growers Research Association (2007) Research priorities, Australian Cotton Growers Research Association, Narrabri, Australia.
- Australian Government Standing Committee on Agriculture (1991) Sustainable Agriculture Report – 36, CSIRO, Commonwealth Government of Australia.
- Australian Government (2001) State of Environment Report, Australian Government, Canberra.
- Australian Government (2003) National Framework for Natural Resources Management Standards and Targets. Natural Resources Management Ministerial Council, April 2003, Australian Government, Canberra, 10 pp.
- Australian Government (2008) National greenhouse gas inventory, Department of Climate Change, Canberra, Australia.
- Australian National Committee Irrigation and Drainage (2002) The 2000/2001 Australian irrigation water provider benchmarking report, Standing Committee on Agriculture and Resource Management, Australian Government, Canberra, Australia.
- Australian Water Resources (2005) Australian Water Resources Report, National Water Commission, Canberra, Australia.
- Baillie C and Chen G (2008) Reducing energy input costs and associated greenhouse gas emissions in cotton. *Proceedings of 14th Australian Cotton Conference, 12–12 August 2008, Broadbeach, Queensland, Australia*, 8 pp.
- Baillie J, Baillie C Heinrich N, Murray A (2007) On farm water use efficiency in the Northern Murray Darling Basin, Murray Darling Basin Commission, Canberra, 246 pp.
- Bange MP, Milroy SP, Thongbai P (2004) Growth and yield of cotton in response to waterlogging, *Field Crops Research*, 88: 129–142.
- Bange M and Constable G (2006) Crop physiology; producing a better fibre, *Proceedings of 13th Australian Cotton Conference, Broadbeach, Queensland 8–10 August 2006*, pp 241–247.
- Bange M, Constable G, McRae D and Roth G (2009 in press) Cotton. In *Climate change for Australian agriculture*, CSIRO, A report for the Australian Government, Land and Water Australia, Canberra.
- Barr N, Karunaratane K, Wilkinson R (2005) Australia's farmers; past, present and future, Land and Water Australia, Australian Government, Canberra, 56 pp.
- Baumgartner L, Reynoldson N, Cameron L and Stanger J (2007) The effects of selected irrigation practices on fish of the Murray Darling basin, NSW Department of Primary Industries final report Series No 92, Cronulla, Sydney.
- Beeton R (2006) Australian Government State of environment report – 2006, Australian Government, Canberra.
- Bell M, Seymour N, Stirling G.R., Stirling A.M. Van Zwieten L, Vancov T, Sutton G and Moody P. (2006) Impacts of management on soil biota in vertosols supporting the broadacre grains industry in northern Australia, *Australian Journal of Soil Research*, 44: 433–451.
- Black A (2005) Rural communities and sustainability. In, *Sustainability and change in rural* Cocklin C and Dibden J (eds), Australia, UNSW Press, Sydney, pp 20–38.
- Boymal J, Rodgers P, Brumby S and Wilder S (2007) Living longer on the land. A health program that works. An economic evaluation of the sustainable farm families program, RIRDC 07/094, Rural Industries Research and Development Corporation, Canberra, 38 pp.
- Bunn SE and Arthington AH (2002) Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity, *Environmental Management*, 30 (4): 492–507.
- Callen V, Christiansen I and Harris G (2004) Knowledge management in cotton and grain irrigation. Australian Cotton CRC Occasional Publication, Narrabri, Australia, 69 pp.
- Cameron Agriculture and Hearn AB (1997) Agronomic and economic aspects of water use efficiency in the Australian cotton industry, Cotton Research and Development Corporation, Narrabri, 58 pp.

- Charles G (2008) Managing herbicide resistance in cotton: the importance of the crop management plan, *Proceedings of 14th Australian Cotton Conference, 12–12 August 2008, Broadbeach, Queensland, Australia*, 11 pp.
- Charles G Taylor I and Roberts G (2004) Integrated weed management in cotton farming systems: why should the industry adopt this approach, *Proceedings of the 12th Australian Cotton Conference, 10–12 August 2004, Broadbeach, Queensland*, pp 313-317.
- Chaudhry RM (2006) Cotton research: world situation, Presented at the 50th anniversary of the national cotton project, Saenz Pena, Chaco, Argentina September 2006, International Cotton Advisory Committee, Washington, USA, 10 pp.
- Chesson J and Whitworth B (2005) Signposts for Australian agriculture – Preliminary framework and collation of industry profiles, Final report stage 1, February 2005, Australian Bureau of Rural Sciences, Australian Government, Canberra, 49 pp.
- Chesson J, Whitworth B and Norton G (2007) Signposts for Australian Agriculture Stage 4a: Completion of six industry profiles, National Land and Water Audit, Canberra. 47 pp.
- Christen E, Shephard M, Jayawardane N, Davidson P, Mitchell M, Maheshwari B, Atkins D, Fairweather H, Wolfenden J and Simmons B. (2006) A guide to using triple bottom line reporting as a framework to promote the sustainability of rural and urban irrigation in Australia, CRC for Irrigation Futures Technical Report No. 03-1/06. Darling Heights, Toowoomba, Queensland.
- Christiansen I and Price J (2002) Cotton information resources survey 2002, Australian Cotton Cooperative Research Centre, Narrabri, NSW, 17 pp.
- Cleland E (2008) Identifying habitat requirements for birds on cotton farms in the lower Namoi, Final report 2.04.12, Cotton Catchment Communities Cooperative Research Centre, Narrabri, 43pp.
- Commonwealth of Australia (1992) National strategy for ecological sustainable development, Department of Environment Water Heritage and the Arts, Canberra, Australia.
- Conaty W, Constable G, Tan D (2006) Genetic variation in cotton for tolerance to waterlogged conditions. *Proceedings of 13th Australian Cotton Conference, 8–10 August 2006, Broadbeach, Queensland*, pp 633-641.
- Constable GA (2007) Producing and preserving fiber quality: from the seed to the bale, *Proceedings of 4th World Cotton Research Conference, 10–14 September 2007, Lubbock, Texas, USA*, 24 pp.
- Constable GA and Rochester IJ (1988) Nitrogen application to cotton on clay soil: Timing and soil testing, *Agronomy Journal*, 80:498-502.
- Constable GA, Rochester IJ and Cook JB (1988) Zinc, copper, iron, manganese and boron uptake by cotton on cracking clay soils of high pH, *Australian Journal of Experimental Agriculture*, 28: 351-356.
- Cooper JL (1992) A grower survey of crops in rotation with cotton in the Macquarie, Namoi, and Gwydir valleys of NSW, Final Report DAN76C, Cotton Research and Development Corporation, Narrabri, NSW.
- Cotton Australia (2002) Cotton Australia 2001/2002 Annual Report, Surrey Hills, Sydney.
- Cotton Australia (2003) Cotton Australia 2002/2003 Annual Report, Surrey Hills, Sydney.
- Cotton Australia (2004) Cotton Australia 2003/2004 Annual Report, Surrey Hills, Sydney.
- Cotton Australia (2005) Cotton Australia 2004/2005 Annual Report, Surrey Hills, Sydney.
- Cotton Australia (2006a) Policy area 3: Sustainability, Cotton Australia Ltd, Surrey Hills, Sydney Australia, 13pp.
- Cotton Australia (2006b) Background Information for the cotton industry BMP review meeting 13th June 2006, Unpublished report, Cotton Australia Ltd, Surrey Hills, Sydney.
- Cotton Australia (2006c) Cotton Australia 2005/2006 Annual Report, Surrey Hills, Sydney.
- Cotton Australia (2007) Cotton Australia 2006/2007 Annual Report, Mascot, Sydney.
- Cotton Australia (2008) Cotton Australia annual report 2007–2008, Mascot, Sydney.
- Cotton Catchment Communities Cooperative Research Centre (2006) Strategic plan 2007–2012, Cotton Catchment Communities CRC, Narrabri, Australia, 4 pp.
- Cotton Catchment Communities Cooperative Research Centre (2007) Cotton Catchment Communities Cooperative Research Centre annual report 2006–2007, Cotton Catchment Communities CRC, Narrabri, Australia.
- Cotton Catchment Communities Cooperative Research Centre (2008) Cotton Catchment Communities CRC, Annual Report 2007–08, Narrabri, Australia.
- Crop Consultants Australia (2007a) The 2006 cotton grower survey benchmarking/BMP land & water report, Report for Cotton Catchment Communities CRC and the Cotton Research and Development Corporation, Narrabri, Australia 217 pp.
- Crop Consultants Australia (2008) 2008 Cotton Consultants Report, A report for the cotton consultants of Australia prepared by Western Research Institute, Narrabri, Australia, 105pp.
- Cotton Research and Development Corporation (1997) The cotton industry best management practices manual (1st Edition), Cotton Research and Development Corporation, Narrabri, Australia.
- Cotton Research and Development Corporation (2000a) Cotton industry benchmark survey: an analysis of the Australian cotton industry, Cotton Research and Development Corporation, Narrabri, Australia.

- Cotton Research and Development Corporation (2000b) The cotton industry best management practices manual (2nd Edition), Cotton Research and Development Corporation, Narrabri, Australia.
- Cotton Research and Development Corporation (2002) Cotton industry benchmark survey: an analysis of the Australian cotton industry for 1999–00 season, unpublished report, Cotton Research and Development Corporation, Narrabri, Australia.
- Cotton Research and Development Corporation (2003) Strategic plan 2003 – 2008, Cotton Research and Development Corporation, Narrabri, Australia.
- Cotton Research and Development Corporation (2006) Soil biology research review. Cotton Research and Development Corporation, Narrabri, Australia, 11 pp.
- Cotton Research and Development Corporation (2007) Annual report 2006–07, Cotton Research and Development Corporation, Narrabri, Australia, 139 pp.
- Cotton Research and Development Corporation (2008) Cotton Research and Development Corporation annual report 2007–08. Cotton Research and Development Corporation, Narrabri, Australia, 133 pp.
- Cotton Research and Development Corporation (2008) Strategic plan 2008–2013, The quest for sustainable competitive advantage, Cotton Research and Development Corporation, Narrabri, Australia, 27 pp.
- Cotter M, Davidson I, Ross H, Brown D, Duncan B and Waters W (2006) Win-win Aboriginal community participation in cotton, *Proceedings of 13th Australian Cotton Conference, 8–10 August 2006, Broadbeach, Queensland*, 7 pp.
- Coutts J, Christiansen I and the Cotton Extension Team (2001) Changes in attitudes to integrated pest management and area wide management in the Australian cotton industry, 1997 – 2001. Australian Cotton Research Centre Occasional Publication No 2003/01, Narrabri NSW, 133 pp.
- Cox PG and Forrester NW (1992) Economics of insecticide resistance management in *Heliothis armigera* (Lepidoptera: Noctuidae) in Australia, *Journal of Economic Entomology*, 85: 1539–1550.
- Crossan A and Kennedy I (2003) A snapshot of roundup ready[®] cotton in Australia, The University of Sydney, NSW. 13 pp.
- CSIRO (2008) Water availability in the Murray Darling Basin. A report to the Australian Government from the CSIRO sustainable yields project, CSIRO, Australia, 67 pp.
- Dall’Alba B (2006) Marketing our product. *Proceedings of 13th Australian Cotton Conference, 8–10 August 2006, Broadbeach, Queensland*, pp 41–50.
- Dall’Alba R (2008) Defining aussie cotton – mainstream or niche? *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 10 pp.
- Day P (2004) Signposts for Australian agriculture: research and development corporations data and reporting, National Land and Water Resources Audit, Australian Government Canberra, 16 pp.
- Deegan C (2001) Implementing triple bottom line, performance and reporting mechanisms – further considerations, Institute of Chartered Accountants, Chartered Magazine, Sydney, Australia, 6 pp.
- Department of Environment Water Heritage and the Arts (2008) Ecologically sustainable development, www.environment.gov.au/esd. (Retrieved 20 November 2008).
- Deutscher S, Wilson L, Mensah R (2004) Integrated pest management guidelines for cotton production Systems in Australia, The Australian Cotton CRC, Narrabri, 78 pp.
- Dodd K (2004) Nutrition in sodic soils. In, *Proceedings of. Farming Systems Forum 2004*. Australian Cotton CRC and Cotton Research and Development Corporation, Narrabri.
- Dorahy C, Rochester I, Blair G (2004) Response of field grown cotton to phosphorus fertilisation on alkaline soils in eastern Australia, *Australian Journal of Soil Research*, 42:913–920
- Downes S, Mahon R, Parker T and Lu B (2008) The Changing Bt Resistance Landscape. *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland, Australia*, 2 pp.
- Dugdale H, Harris G, Nielsen J, Richards D, Roth G and Williams D (2008) WATERpak, A guide for irrigated management in cotton and grains, Cotton Research and Development Corporation and Cotton Catchment Communities CRC, Narrabri, Australia.
- Dukhovny V, Yakubov K, Usmano A and Yakubov M (2002) Drainage water management in the Aral Sea basin, In *Agricultural Drainage Water Management in Arid and Semi Arid Areas*, Food and Agriculture Organisation Drainage Paper 61, Tanji KK and Kielen NC (eds), Food and Agriculture Organisation of The United Nations, Rome, 188pp.
- Earle J (2003) The distribution and impacts of lippia (*Phyla canescens*) in the Murray Darling Basin. A report for the Murray Darling Basin Commission, Canberra.
- Elkington J (1997) Cannibals with forks: The triple bottom line of 21st century business, Capstone, Oxford.
- Environment Australia (2003) Triple bottom line reporting in Australia. A guide to reporting against environmental indicators, Department of Environment and Heritage, Canberra, 68 pp.
- Farrell T (2009) Cotton pest management guide 2008–09, NSW DPI, Australian Cotton Research Institute, Narrabri, Australia, 142 pp.
- Felton WL, Marcellos H and Martin RJ (1995) A comparison of three fallow management strategies for the long-term productivity of wheat in northern New South Wales, *Australian Journal of Experimental Agriculture*, 35 (7): 915–921.
- Fitt G (2003) Implementation and impact of transgenic Bt cotton in Australia, *Proceedings of 3rd World Cotton Research Conference, 9–13 March 2003, Capetown, South Africa*, pp 371–381.
- Fitt G and Wilson L (2002) Non target effects of Bt cotton: a case study in Australia, *Proceedings of the 4th Pacific Rim Conference, CSIRO, Canberra*, pp175–184.

- Fitzpatrick C (2008) What do consumers want from textiles, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 3pp.
- Foley JP and Raine SR (2001) Centre pivots and lateral move machines in the Australian Cotton industry, National Centre for Engineering in Agriculture, Toowoomba, Australia, 39 pp.
- Ford G and Thompson N (2006) Birds on cotton farms, A guide to common species and habitat management, Cotton Catchment Communities CRC, Narrabri, Australia, 125 pp.
- Frager LJ, and Thomas P (2005) Machine injuries on Australian farms – The facts, Australian Centre for Agricultural Health and Safety, Publication No. 05/050; Rural Industries Research and Development Corporation, Canberra, 16pp.
- Frager LJ, Sankaran B, Thomas P (2005) Pesticides and adverse health outcomes in Australia – The facts, Australian Centre for Agricultural Health and Safety, Publication No. 05/051; Rural Industries Research and Development Corporation, Canberra, 16pp.
- Frager L and Temperley J (2008) The impact of biotechnology and other factors on health and safety in the Australian Cotton Industry, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 8pp.
- Franklin R, Frager L, Houlahan J, Brown P, Burcham J (2001) Health and safety risks associated with cotton production on farm, National Farm Injury Centre, Australian Centre for Agricultural Health and Safety, Moree, 40 pp.
- Freudenberger D and Drew A (2001) Bird surveys in travelling stock routes and reserves on the northwest slopes and plains, A report for Northern Slopes Rural Land Protection Boards NSW, CSIRO Ecosystems, Canberra. 38 pp.
- Fricker A (1998) Measuring up to sustainability, *Futures*, 30(4) 367-375.
- Gallopín, GC (1997) Indicators and their use: Information for decision making. *In*, Scope 58: sustainability indicators: a report on the project on indicators of sustainable development by the scientific committee on problems of the environment, Moldan E, Billharz S, Matravels R (eds), United Nations Environment program, John Wiley & Sons, New York, pp 13-28.
- GHD (2003) Second Australian cotton industry environmental audit, A report for the Cotton Research and Development Corporation, Narrabri, Australia, 180 pp.
- GHD (2008) Murray Darling Basin water entitlements, Summary of recent market prices 2007–08, Department of Environment Water Heritage and the Arts, Canberra.
- Gibb (1991) An environmental audit of the Australian cotton industry, Gibb Environmental Sciences and Arbour International, October 1991.
- Global Reporting Initiative (2002) Sustainability reporting guidelines, Global Reporting Initiative Boston, MA, USA, 94 pp.
- Global Reporting Initiative (2006) G3 sustainability reporting guidelines, Global Reporting Initiative Boston, MA, USA, pp 28-33.
- Global Reporting Initiative (2008) Sustainability reporting in the food processing sector, Global Reporting Initiative, Amsterdam, The Netherlands, 20 pp.
- Grace P (2008) A cotton farm's carbon and greenhouse footprint, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 3pp.
- Gregg P and Wilson L (2008) The changing climate for entomology, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland, Australia*, 11 pp.
- Grismer ME (2002) Regional cotton lint yield, E_c and water value in Arizona and California, *Agricultural Water Management* 54: 227-242.
- Gunawardena TA, McGarry D, Gardner EA, Stirzaker R (2008) Managing deep drainage for improved WUE: Solute monitoring and groundwater response in the irrigated landscape, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 8 pp.
- Hardi P (1997) Measurement and Indications Program of the International Institute for Sustainable Development; *In*, Scope 58: sustainability indicators. A report on the project of indicators of sustainable development. Moldan E, Billharz S, Matravels R (eds) United Nations Environment Program, John Wiley & Sons New York, pp 28-33.
- Harris G (2007) Benchmarking water management in the Australian cotton industry, Spotlight Magazine, Cotton Research and Development Corporation, Narrabri, Page 6.
- Hassall and Associates (2005) Indicators for triple bottom line benchmarking of GRDC farming systems projects, Grains Research and Development Corporation, Canberra, 18 pp.
- Hassall and Associates (2006) Evaluation of the Australian Cotton Industry's BMP Proceedings, Report prepared for Cotton Research and Development Corporation, Cotton Australia, February 2006, Unpublished report, 65 pp.
- Hearn AB (1981) Cotton nutrition, *Field Crop Abstracts*, 34(1): 11-34.
- Hearn AB (1994) The principles of cotton water relations and their application in management. *Proceedings of the World Cotton Research Conference, Brisbane, Australia February 14–17 1994*, pp 66-92.
- Hearn AB and Constable GA (1984) Cotton. *In* Goldsworthy, PR and Fisher NM (eds.) The physiology of tropical food crops, John Wiley and Sons Ltd, pp 495-527.
- Herron GA, McLoon MO, Wilson LJ (2008) Resistance testing summary for the 2006–2007 and 2007–2008 cotton seasons: cotton aphid *Aphis gossypii* and two-spotted mite *Tetranychus urticae*, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland, Australia*, 6 pp.

- Hickman M, Rochester I, Tennakoon, S, Hare C, Hulugalle N, Charles G, Allen S, Nehl D, Scott F, Cooper J, Conteh A (1998) Rotation crops: what is the impact on an irrigated farming system, *Proceedings of 9th Australian Cotton Conference, 12–14 August 1998, Broadbeach, Queensland*, pp 49-59.
- Hickman M (2008) Vocational extension: a new cotton era is dawning, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 5 pp.
- Higgins S and Adcock L (2008) New Beginnings for BMP. *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 6 pp.
- Hodgson A and MacLeod D (1988) Seasonal and soil fertility effects on the response of waterlogged cotton to foliar applied nitrogen fertiliser, *Agronomy Journal*, 80: (2)259-265.
- Holloway R and Roth G (2003) Grower feedback on cotton BMP auditing, *The Australian Cottongrower magazine*, February – March 2003 pp 20-22.
- Howden M (2008) Climate change and its implications for cotton production, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 9 pp.
- Hulugalle NR and Scott F (2008) Rotations – maintaining our soil quality and profitability, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, pp 211-222.
- Hulugalle NR and 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.
- Hutchinson KJ King KL and Wilkinson DR (1995) Effects of rainfall, moisture stress, and stocking rate on the persistence of white clover over 30 years, *Australian Journal of Experimental Agriculture*, 35 (7): 1039-1047.
- Inglis G and Shaw G (2000) Cotton Industry Benchmark Survey: An analysis of the Australian Cotton Industry. A report on the 1996/97 Benchmarking survey, Australian Cotton Cooperative Research Centre and Cotton Research and Development Corporation, Narrabri, NSW, pp 36.
- International Cotton Advisory Committee (2008) Statement from 67th plenary meeting of International Cotton Advisory Committee, Washington, USA.
- International Cotton Advisory Committee (2009) World cotton situation, January 22nd 2009, International Cotton Advisory Committee, Washington, USA.
- Inter Governmental Agreement on the Environment (1992) Section 3, principles of environment policy May 1992, Australian Heads of Government, Canberra.
- International Union for Conservation of Nature and Natural Resources (1980) World Conservation Strategy, Living Resource Conservation for Sustainable Development, Switzerland.
- Jarman PJ and Montgomery J (2002) Waterbirds and irrigation storages in the Lower Gwydir valley, NSW, Report for the Natural Heritage Trust, Canberra, 36 pp.
- Jessop T, Constable G, MacLeod D (1993) What is the salinity threat with continued irrigation, *The Australian Cottongrower*, 14(5), 18-19.
- Johnson D, Headey B and Jensen B (2005) Policy Research Paper Number 26. Communities, Social capital and public policy: literature review, Department of Family and Community Services, Canberra, 74 pp.
- Kemp DR, Michalk DL, Charry AA (2001) The development of ecological performance indicators for sustainable systems, *Proceedings of the 10th Australian Agronomy Conference, 2001, Hobart, Tasmania*, 9pp.
- Kingsford R Auld K (2005) Waterbird breeding and environmental flow management in the Macquarie marshes, arid Australia, *River Research and Applications*, 21: 187-200.
- Knox O (2006) Rhizosphere biological functions as influenced by GM cotton, Final Report for the Cotton Research and Development Corporation, Narrabri 229 pp.
- Lake PS (1995) Of floods and droughts: River and stream ecosystems of Australia, *In River and Stream Ecosystems*, (Eds Cushing CE, Cummins KW, and Marshall GW), Elsevier, Amsterdam, pp 659-694.
- Langas S (1997) The spatial dimensions of indicators of sustainable development, The role of GIS and cartography, *In*, Scope 58: sustainability indicators. A report on the project of indicators of sustainable development, Moldan E, Billharz S, Matravars R (eds) United Nations Environment program, John Wiley & Sons New York, pp 33-40.
- Lovett S, Price P, Lovett J (2003) Managing riparian lands in the cotton industry, Cotton Research and Development Corporation, Narrabri, 106 pp.
- Maas S and Chapman V (2005) Water and soil quality Australian cotton Industry BMP, Information Sheet, Cotton Catchment Communities CRC, 2 pp.
- Macarthur Agribusiness (2003) Evaluation of the Australian Cotton Industry Best Management Practices Program, Cotton Australia, Surrey Hills, Sydney, 43pp.
- MacKinnon L (2005) Insectivorous bats, irrigated cotton, native vegetation remnants and intensive production landscapes, Final Report Australian Cotton CRC 2004–05, Narrabri, Australia.
- Mahwinney W (2004) Water quality in the Namoi, *In WATERpak*, A guide for irrigated management in cotton and grains, Cotton Research and Development Corporation and Cotton Catchment Communities CRC, Narrabri, Australia, pp 265-272.
- Mahwinney W (2008 in press) Water quality in the Barwon region, Department of Water and Energy, Tamworth, NSW.
- Maisra R and Hood S (2007) Desktop review of polyacrylamide use in the Australian cotton industry, National Centre for Engineering in Agriculture, Publication 1002542, USQ, Toowoomba.

- Martyn S, Morton M and Leahy A (2006) The Australian cotton industry: where has it come from, where is it going and what will it take, *Proceedings of 13th Australian Cotton Conference, 8–10 August 2006, Broadbeach, Queensland*, pp 87-93.
- McGarry D (1990) Soil compaction and cotton growth on a vertosol, *Australian Journal of Soil Research*, 28:869-877.
- McGarry D (1995) The optimisation of soil structure for cotton production, *Proceedings of the World Cotton Research Conference 1, 14–17 February 1994, Brisbane Queensland*, pp 169-176.
- McHugh A D Bhattarai S Lotz G Midmore DJ (2008) Effects of subsurface drip irrigation rates and furrow irrigation for cotton grown on a vertosol on off site movement of sediments, nutrients and pesticides, *Agronomy Sustainability Development* 28: 507-519.
- McKenzie DC (1990) SOILpak for cotton growers, NSW Agriculture, Orange.
- McKenzie, DC (2007) Prioritising the properties: Soil structure. *Proceedings of the Healthy Soils Symposium, Twin Waters, Sunshine Coast, Queensland, July 3-5*, pp22-26.
- McKenzie DC, Shaw AJ, Rochester IJ, Hulugalle NR, Wright PR, (2003) Soil and nutrient management for irrigated cotton, AGDEX 151/510, no. P5.3.6, New South Wales Agriculture, Orange, New South Wales, 40 pp.
- McMaster LC and McMaster JS (2001) Developing an environmental management systems framework for processing tomatoes, *Proceedings of VIII ISHS Symposium on Proceedings Processing Tomatoes, Istanbul, Turkey*, 8 pp.
- Measham T, Gorddard R, Stayner R (2006) Scoping the selection of baseline socio economic indicators for cotton communities, Final Report Cotton Catchment Communities CRC, Narrabri NSW, 23 pp.
- Metcalfe RL and Luckmann WH (1994) *Introduction to insect pest management*, (3rd edition), John Wiley and Sons, New York, pp 258-259.
- Mitchell M, Curtis A, Davidson P (2008) Evaluating triple bottom line reporting: Increasing the potential for change, *Local Environment* 13(2):67-80.
- Montagu K, Thomas B, Thomas G, Christian, E, Hornbuckle J, Baille C, Linehan C, Smith P, Galla F, North S, Meyer W, Stirzaker R, Cornish P (2006) Understanding irrigation decisions, From enterprise to paddock, National Program for Sustainable Irrigation, Irrigation Insights 6, Land and Water Australia, Canberra, 75 pp.
- Montgomery J and Faulkner R (2004) Case study, water quality in the Gwydir valley water courses, *In WATERpak, A guide for irrigated management in cotton and grains*, Cotton Research and Development Corporation and Cotton Catchment Communities CRC, Narrabri, Australia, pp 273-280.
- Murray Darling Basin Commission (2008) Sustainable rivers audit, Murray Darling Basin Rivers: ecosystem health check, 2004–2007, Murray Darling Basin Commission, Canberra, 70pp.
- National Program for Sustainable Irrigation (2009) Facts and figures on irrigation, National Program for Sustainable Irrigation, Land and Water Australia, Canberra.
- Natural Resources Commission (2005) Recommendations state wide standard and targets, Natural Resources Commission, Sydney, 142 pp.
- National Land and Water Resources Audit (2002) Australia's natural resources 1997–2002 and beyond, National Land and Water Audit, Canberra, 141 pp.
- National Land and Water Resources Audit (2005) National Land and Water Audit Australian Agriculture framework for economic and social indicators, National Land and Water Audit, Australian Government, Canberra.
- National Land and Water Resources Audit (2008) Signposts for Australian Agriculture. The Australian cotton Industry. National Land and Water Audit, Australian Government, Canberra, 89pp.
- Newnham D (2006) The cotton industry comparative analysis. Boyce Chartered Accountants, Moree, Report for Cotton Research and Development Corporation, Narrabri, NSW, Australia.
- NSW Department of Water and Energy (2008) Lower Namoi groundwater water sharing plan. NSW Department of Water and Energy, Sydney.
- Norton R (2007) Learning from long term experiments – what do they tell us ? *Proceedings of the Healthy Soils Symposium, Twin Waters, Sunshine Coast, Queensland, July 3–5*, pp 111-119.
- Norton MR, Murison R, Holford ICR and Robinson GG (1995) Rotation effects on sustainability of crop production: the Glen Innes rotation experiment, *Australian Journal of Experimental Agriculture* 35 (7), 893-902.
- Parkes A (2004) Production – doing our best. *Proceedings of 12th Australian Cotton Conference, 10–12 August 2004, Broadbeach, Queensland 10–12 August 2004*, pp 73-82.
- Parliamentary Joint Committee on Corporations and Financial Services (2006) Corporate responsibility: managing risk and creating value, Parliament House, Canberra.
- Partridge R (2004) Remnant native vegetation on cotton farms in the Moree Shire: comparison of vegetation condition assessment tools and their efficacy in protecting bird species. The University of New England, unpublished Honours Thesis.
- Payero JO and Harris G (2007) Benchmarking water management in the Australian cotton industry. Unpublished report submitted to the Cotton Catchment Communities CRC, September 2007, Narrabri, Australia, 124 pp.
- Powell R and Chalmers L (2009) The economic structure of cotton regions and the economic impact of the cotton industry, Centre for Agricultural and Resource Economics, Armidale, Report for the Cotton Catchment communities CRC, Narrabri.

- Pretty J (2005) Sustainability in Agriculture: Recent Progress and Emergent Challenges. In *Issues in Environmental Science and Technology*, No 21 Sustainability in Agriculture, Hester RE and Harrison RM (eds), The Royal Society of Chemistry Publishing, pp 1-15.
- Pritchard B, Curtis A, Spriggs, J and Leheron R (eds) (2003) Social dimensions of the triple bottom line in rural Australia, Australian Government, Bureau of Rural Sciences, Canberra.
- Pyke B (2007) The impact of high adoption of Bollgard II cotton on pest management in Australia, *Proceedings of the 4th World Cotton Research Conference*, Lubbock, Texas, USA 20pp.
- Raine SR, Foley JP and Henkel CR (2000) Drip irrigation in the Australian cotton Industry: A scoping study, National Centre for Engineering in Agriculture, Toowoomba, Australia, 33 pp.
- Raine SR, Purcell J, Schmidt E (2006) Improving whole farm and in field irrigation efficiencies. *International Water & Irrigation* 26 (2): 12-14.
- Reeve I, Stayner R, Doyle B, McNeil J (2003) A scoping study on social economic indicators for the cotton industry, A report to the Cotton Research and Development Corporation, The University of New England, Armidale, 65 pp.
- Reid N, O'Shea G, Silberbauer L (2003) A review of biodiversity research in the Australian cotton Industry. Final report to the Cotton Research and Development Corporation, December 2003, Narrabri Australia, 240 pp.
- Reid N, Karanja F and Thompson D (2006) Ecosystem services and biodiversity indicators. *Proceedings of 13th Australian Cotton Conference, Broadbeach, Queensland*, pp127-138.
- Riding T and Carter R (1992) The importance of the riparian zone in water resource management, A literature review, Department of Water Resources, Parramatta, NSW, 12 pp.
- Rochester I (2001) NUTRIpak – A practical guide for cotton nutrition, Published by the Australian Cotton Cooperative Research Centre, Narrabri, NSW.
- Rochester I and Constable G (2005) Nutrients removed in harvested seed cotton, Cotton Catchment Communities CRC, Narrabri, 6 pp.
- Rochester IJ and Peoples MB (2005) Growing vetches (*Vicia villosa* Roth) in irrigated cotton systems: inputs of fixed N, N fertilizer savings and cotton productivity, *Plant and Soil* 271:251-264.
- Rochester I (2008) Optimizing N fertiliser use and N fertiliser use-efficiency, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 6 pp.
- Rochester I, O'Halloran J, Maas S, Sands D, Brotherton E (2007) Monitoring nitrogen use efficiency in your region. The Australian Cottongrower, August – September 2007, pp24-26.
- Ross C (2008) Alignment of Best Management Practices, Cotton Australia Annual Report 2007/2008, Sydney, NSW, 27 pp.
- Ross C and Galligan D (2005) The integration of Cotton BMP with a sub catchment planning approach, *Proceedings of 4th National EMS in Agriculture Conference, Beechworth, Victoria, October 2005*, 4pp.
- Rose M, Sanchez Bayo F, Crossan A, Kennedy I (2006) Pesticide removal from cotton farm tailwater by a pilot scale ponded wetland, *Chemosphere* 63: 1849-1858.
- Rossiter L, Gunning R and McKenzie F (2008) Silver Anniversary of Resistance Management in the Australian Cotton Industry. An overview and the current situation for *Helicoverpa armigera*. *Proceedings of 14th Australian Cotton Conference*, Broadbeach, Queensland, Australia. 8 pp
- Roth G (2001) Soils research and development, A workshop summary, Cotton Research and Development Corporation, Narrabri, 5pp.
- Roth GW (2003) Measuring the sustainability of cotton production systems, *Proceedings of 3rd World Cotton Research Conference*, Capetown, South Africa, 9–13 March 2003, 8 pp.
- Roth GW (2003) Protecting our riparian land, The Australian Cottongrower Yearbook, The Australian Cottongrower Magazine, pp 94-98.
- Roth GW (2007) Towards sustainable and profitable water use in the Australian Cotton Industry, Occasional Publication, Cotton Catchment Communities CRC, Narrabri, Australia, 11 pp.
- Roth G and Cull P (1991) Soil compaction and the deficit, The Australian Cottongrower Magazine, Jan/Feb, pp 10-11.
- Roth G and Drew T (2004) The impact of drought on small business, Cotton Information Sheet, Australian Cotton CRC, Narrabri, 4 pp.
- Roth G and Squires H (2007) How far has soil health come in the cotton industry. *Proceedings of the Healthy Soils Symposium, Twin Waters, Sunshine Coast, Queensland, July 3–5*, pp 131-139.
- Roy Morgan Research (2000) Cotton Australia attitudinal research, Report for the Australian Cotton Foundation, Sydney, Australia
- Roy Morgan Research (2004) Attitudinal research in cotton communities and opinion centres. A report for Cotton Australia and Cotton Research and Development Corporation, Cotton Australia, Sydney.
- Rural Water Use Efficiency Initiative (2003) Cotton and grains adoption program milestone 4 report compiled by P Goynne, Queensland Government Departments of Primary Industries and Natural Resources and Mines.
- Scott JM (2005) Can there be a magic pudding? Towards an understanding of viable farms. The 2005 Inaugural Public Lecture Series, The University of New England, Armidale, pp 43.
- Seymour N, Knox O and Vadakattu G (2006) Understanding soil biology, *Proceedings of 13th Australian Cotton Conference 8–10 August 2006, Broadbeach, Queensland*, pp311-315.
- Schofield N, Williams A, Holloway R and Pyke B (2005) Minimising riverine impacts of endosulfan used in cotton farming – A science into practice success story, *Proceedings of Pacificchem Symposium 2005, Honolulu, USA, Dec 15–20 2005*, 17 pp.
- Shaw G (2005) Soil health issues for the Australian cotton production: a growers perspective Survey Report, Cotton Research and Development Corporation, Narrabri, 31 pp.

- Silburn DM, Waters DK, Connolly, RD, Simpson BW and Kennedy IR (1988) Techniques for stabilising soil erosion on cotton farms, *Proceedings of 1998 Pesticides Conference LWRDC & CRDC*, Canberra, pp 99-105.
- Shimazaki T (2008) Winning back markets for Australian cotton, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 7 pp.
- Silburn M and Montgomery J (2004) Deep drainage under irrigated cotton. A review. In Dugdale H, Harris G, Nielsen J, Richards D, Roth G and Williams D (2008) *WATERpak. A guide for irrigated management in cotton and grains*. Cotton research and Development Corporation and Cotton Catchment Communities CRC, Narrabri, Australia, pp29-40.
- Sinclair Knight Metz (2003) IMIRS Stage 2 – Cotton Industry Case Study, Murray Darling Basin Commission, Canberra, 76 pp.
- Smith RJ (2005) Biodiversity of tree plantings in cotton growing areas of the Namoi Valley, The University of New England, unpublished Honours Thesis, The University of New England, Armidale.
- Smith RJ, Raine SR, Minkevich J (2005) Irrigation application efficiency and deep drainage potential under surface irrigated cotton, *Agricultural Water Management* 71:117-130.
- Smith CS and McDonald GT (1998) Assessing the sustainability of agriculture at the planning stage, *Journal of Environmental Management*, 52: 15-37.
- Smith R and Roth G (2004) Case study, water quality monitoring: Dirranbandi, In *WATERpak, A guide for irrigated management in cotton and grains*, Cotton Research and Development Corporation and Cotton Catchment Communities CRC, Narrabri, Australia, pp 259-264.
- Spanswick S (2006) Land and water best management practice. Challenges and rewards for achieving profit, *Proceedings of 13th Australian Cotton Conference, Broadbeach, Qld*, pp 147-154.
- Spanswick S, Roth G, Drew T, and Jones P (2007) The impact of drought on small business. A pilot study on Wee Waa, People & Community Series: Cotton Catchment and Communities CRC publication, 4 pp.
- Spanswick S and Jones P (2008) Working with regional natural resource management bodies to improve water management, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 6pp.
- Spellson A (2008) What we are doing with your BMP Cotton, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 14pp.
- Standing Committee on Agriculture and Resource Management (1998) Sustainable Agriculture. Assessing Australia's Recent Performance. Standing Committee on Agriculture and Resource Management, Technical Report 70, CSIRO Publishing, Melbourne
- Stanley J, Roth G, Gibb D and Jessop R (2003) Schooling the Australian cotton industry, *Proceedings of 3rd World Cotton Research Conference, 9–13 March 2003, Capetown, South Africa*.
- Stoneham G, Eigenraam M, Ridley A and Barr N (2003) The application of sustainability concepts to Australian agriculture: an overview, *Australian Journal of Experimental Agriculture*, 43 pp 195-203.
- Stollznow Research (1995a) Investigation and monitoring of consumer attitudes towards the cotton industry, Report for the Australian Cotton Foundation (now Cotton Australia) Sydney, pp 147.
- Stollznow Research (1995b) Sydney community perception of the cotton industry and related matters, Report for The Australian Cotton Foundation, Sydney, Australia.
- Stollznow Research (1997) Investigation and monitoring of community attitudes toward the cotton industry in country areas and qualitative investigation of community attitudes towards cotton growing, Report for the Australian Cotton Foundation, Sydney, Australia.
- Stollznow Research (1998) Investigation and monitoring of community attitudes toward the cotton industry in country areas and qualitative investigation of community attitudes towards cotton growing in NSW and Queensland towns, Report for the Australian Cotton Foundation, Sydney, Australia
- Stubbs J, Lux L and Powell R (2008) Measuring community wellbeing in cotton communities, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 9 pp.
- Sustainability Ltd (2005) Sustainability: Tomorrows world, www.sustainability.com/aboutus. (Accessed: 20th March 2005).
- Taylor I Charles G and Chapman C (2006) The critical period for weed control: Improving weed management decisions in herbicide tolerant cotton based on a weed control threshold, *Proceedings of 13th Australian Cotton Conference, 8–10 August 2006, Broadbeach, Queensland*, pp 267-273.
- Tennakoon SB and Milroy SP (2003) Crop water use efficiency on irrigated cotton farms in Australia, *Agricultural Water Management*, 61: 179-194.
- The University of Sydney (2004) Australian Cotton CRC soil database and soil information system, The University of Sydney, Sydney, NSW.
- Thompson JP, Mackenzie J and Amos R (1995) Root-lesion nematode (*Pratylenchus thornei*) limits response of wheat but not barley to stored soil moisture in the Hermitage long-term tillage experiment, *Australian Journal of Experimental Agriculture* 35 (7) 1049-1055.
- Thoms M and Cullen P (1998) The impact of irrigation withdrawals on inland river systems, *Rangelands Journal*, 20(2) 226-236.
- Townsend T (2006) The world situation. Paper presented to 82nd annual convention of the American Cotton Shippers Association, May 11–13 2006, Palm Beach, Florida. International Cotton Advisory Committee, Washington, USA, 3 pp.
- Triantafyllis J (2007) TerraGIS natural resource management for cotton growing regions, www.terragis.bees.unsw.edu.au. (Retrieved 18th June 2008).

- Triantafyllis J, Buchanan S, Short M, and Malik R (2004) Mapping subsurface saline material at Bourke, The Australian Cottongrower Magazine, Feb-March, pp59-61.
- United Nations (1992) Earth Summit. Agenda 21. Rio Declaration on environment and development. United Nations General Assembly, Rio de Janeiro www.un.org/esa/sustdev/documents/agenda21, 3–14 June 1992.
- Van der Sluijs MHJ, Gordon SG and Naylor GR (2004) Australian fibre quality: Smart decisions. *Proceedings of 12th Australian Cotton Conference, 1–12 August 2004, Broadbeach, Queensland*, pp 159-174.
- Vervoot RW, Cattle SR, Minasny B (2003) The hydrology of vertisols used for cotton production: Hydraulic, structural and fundamental soil properties, *Australian Journal of Soil Research* 41, 1255-1272.
- Visijayshankar MN (2006) Processing your product using Australian cotton, *Proceedings of 13th Australian Cotton Conference, 8–10 August 2006, Broadbeach, Queensland*, pp 49-56.
- Walker J (2002) Environmental Indicators and Sustainable Agriculture. In McVicar T.R, Li Rui, Walker J, Fitzpatrick RW, and Liv Changing (eds), *Regional Water and Soil Assessment for managing Sustainable Agriculture in China and Australia*, ACIAR Monograph No 84; pp 323-332.
- Walker J, Alexander D, Irons C, Jones B, Penridge H and Rapport D (1996) Catchment health indicators: an overview. In *Indicators of catchment health, a technical perspective*. J Walker and DJ Reuter (eds) CSIRO, Canberra, pp 3-21.
- Warnock J (1983) Trial of sub surface drip irrigation of cotton with RIS Bi Wall, The Australian Cottongrower Magazine, January, pp38-39.
- Waters D (2004) Water quality in Queensland catchments and the cotton industry, In *WATERpak, A guide for irrigated management in cotton and grains*, Cotton Research and Development Corporation and Cotton Catchment Communities CRC, Narrabri, Australia, pp 281-287.
- Western Research Institute (2007a) 2006/07 Grower feedback report. Cotton growers post season survey, Prepared for Crop Consultants Australia, Narrabri, NSW 63 pp.
- Western Research Institute (2007b) 2006/07 CCA consultant post season survey, Prepared for Crop Consultants Australia, Narrabri, NSW 168 pp.
- Western Research Institute (2007c) 2007 Market audit report, Prepared for Crop Consultants Australia Inc, Narrabri, NSW, 88 pp.
- Webb, McKeown & Associates (2007) State of the Darling Hydrology report, Murray Darling Basin Commission, Canberra, 61 pp.
- Williams A (2007) Enhancing the cotton industry's BMP Program to improve adoption. Final report for EMS pathways program project. Cotton Research and Development Corporation, Narrabri and Department of Agriculture Fisheries and Forestry, Canberra.
- Williams A, Leutton R, Rouse A and Cairns R (2004) The Australian cotton industry: Turning natural resource management policy into on ground action, OECD Expert Meeting on farm Management Indicators and the Environment, Palmerston North, New Zealand 8–12 March 2004, 18 pp.
- Williams A and Williams J (2001) Fostering best management practices in natural resource management – towards an environmental management system in the cotton industry, Cotton Research and Development Corporation, Murray Darling Basin Commission, Canberra and Australian Cotton Growers Research Association, Wee Waa. 357 pp.
- Williams D and Montgomery J (2008) Bales per megalitre. An industry wide evaluation of the 2006–07 season, *Proceedings of 14th Australian Cotton Conference, Broadbeach, Queensland*, 13pp.
- Wilson AGL (1974) Resistance of *Heliothis armigera* to insecticides in the Ord Irrigation Area, north western Australia, *Journal of Economic Entomology*, 67: 256-258.
- World Wildlife Fund (2005) Case Study: Development of the Australian cotton industry Best Management Practice (BMP) program, Published by Cotton Australia, Sydney.
- World Commission on Environment and Development (1987) Our common future the Brundtland Commission. World Commission on the Environment and Development 1987, Australian Edition Melbourne: Oxford University Press.
- Worster D (2004) Dust Bowl, The southern plains in the 1930s, Oxford University Press, New York, 285 pp.
- Wright PR (1999) Premature senescence of cotton (*Gossypium hirsutum* L.) – predominantly a potassium disorder caused by the imbalance of source and sink, *Plant and Soil* 211:231 – 239.
- Yeates S, Strickland G, Moulden J and Davies A (2007) NORpak – Cotton production and management guidelines for the Ord River irrigation Area, Cotton Catchment Communities CRC & CSIRO, Narrabri, NSW, 51 pp.
- Yeates S, Roberts J and Richards D (2008) Toward better water management of Bollgard II cotton, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Qld*. 7 pp.
- Yung L (2008) The changing world textile market, *Proceedings of 14th Australian Cotton Conference, 12–14 August 2008, Broadbeach, Queensland*, 7 pp.

