# Appendix C Case study: Cotton Varieties

**SUMMARY OF KEY FINDINGS**

- CSIRO's cotton breeding research project has delivered net benefits to Australia of approximately $149.3 million in 2014 dollar terms between 2006/7 and 2013/14, representing an internal rate of return of 93 per cent over original input costs.
- ACIL Allen anticipates future benefits of over $379.5 million over the next decade under a 5 per cent discount rate as a result of cotton yield productivity increases due to CSIRO's research project.
- CSIRO's cotton research project has increased the productivity of Australia's cotton yield due to the breeding of cotton varieties that are more resistant to common diseases, are more water efficient, and are better adapted to Australian weather and soil conditions.
- There are a number of important benefits have not been included in our cost-benefit calculations, but which have nonetheless delivered benefits to Australia over the lifespan of CSIRO's cotton varieties research project. These include:
  - improved ecological health and lower exposure of farmers and farming communities to pesticides as a result of reduced pesticide use,
  - increased water efficiency – Australian cotton farming is now the most water-efficient in the world – and;
  - increased sustainability of local farming communities, due to the increased resilience of the cotton industry to risks such as disease and drought.

## C.1 Introduction

### C.1.1 Purpose and audience

This independent case study evaluation has been undertaken to assess the economic, social and environmental impact of CSIRO research on cotton varieties.  This case study has been prepared so it can be read as a standalone report or aggregated with other case studies to substantiate the impact and value of CSIRO's activities.

The report is provided for accountability, reporting, communication and continual improvement purposes. Audiences for this report may include Members of Parliament, Government Departments, CSIRO and the general public.

### C.1.2 Background

**The cotton industry is very important to Australia**

The cotton industry is one of Australia's major agricultural industries. Cotton exports in 2012-13 were valued at $2.7 billion. Wheat was the only crop with exports ($6.8 billion) that exceeded this value, while wool exports were valued at $2.9 billion and canola exports at $2.1 billion in that same year (ABARES, 2013). Australia is one of the world's top four cotton exporters (Cotton Australia, 2014b), although there is considerable variability in annual cotton production in Australia, largely determined by availability of irrigation water (Figure C1).

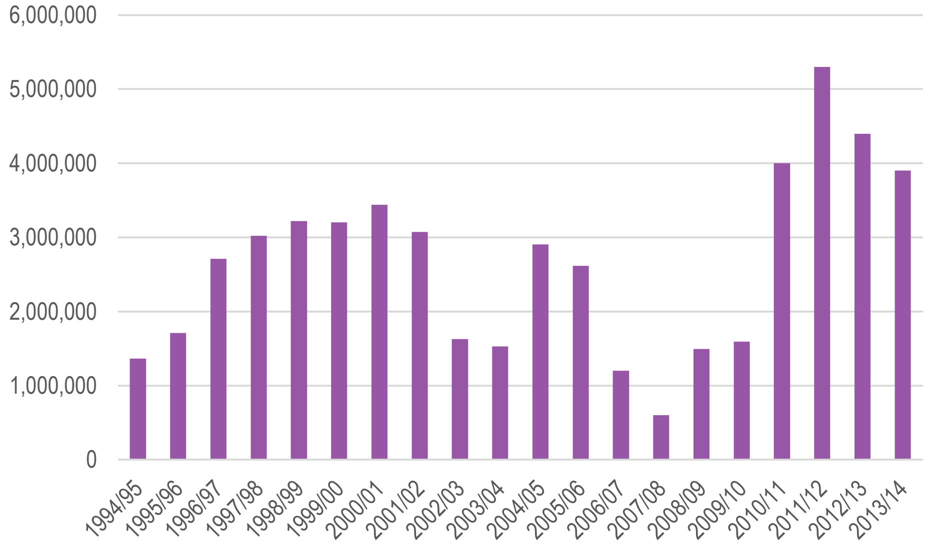
Prior to the early 1960s, cotton growing in Australia was undertaken on a relatively small scale. However, the nature of the industry transformed with the introduction of high-input irrigation cotton growing in NSW, Queensland and WA, enabled in part by new dam construction. While cotton production ceased in WA in 1974 following the emergence of insecticide-resistant pests, production in NSW and Queensland has increased considerably over time (Constable *et al.*, 2001). During the 1960s and 1970s, all cotton varieties grown in

Australia were sourced exclusively from the USA. In this period, separate breeding programs emerged that were mainly funded by state agriculture Departments or through the CSIRO.

**CSIRO's Cotton Research unit consolidated all of Australia's cotton R&D**

In the early 1970s it was recognised that the various cotton breeding programs were disparate and uncoordinated and that they were located away from the main cotton production centre in northern-western NSW (Narrabri). The various cotton breeding programs were eventually closed and responsibility for Australia's cotton breeding research was taken up by CSIRO, with the establishment of the CSIRO Cotton Research unit at Narrabri in 1972. Thereafter, CSIRO commenced a breeding program that sought to develop full-season varieties for Australia's primary cotton growing regions (Constable *et al.*, 2001).

Figure C1 **Cotton production in Australia - Bales**




Note: The 2013/14 crop is a forecast.
Source: Cotton Australia 2014c

**CSIRO is developing cotton varieties that suit Australia's unique conditions**

Since 1972, CSIRO's Cotton breeding group has sought to develop cotton varieties that are capable of maximising productivity and quality under Australia's unique conditions, with major breeding goals including:

- increased yield and regional adaptation
- resistance to diseases
- pest resistance
- increased fibre quality to compete in premium export markets.

**The aim is to improve productivity and quality**

CSIRO has developed four major cotton variety types – 'Siokra', 'Sicala', 'Sicot' and 'CS' – from which a number of varieties have been developed. CSIRO's first breakthrough in cotton varieties development was Siokra 1-1, released in the early 1980s, which features a slender, okra-shaped leaf (versus the larger, rounder leaf of normal cotton strains). Smaller, thinner leaves make Siokra cotton more water efficient that round leaf varieties. Siokra is also resistant to bacterial blight and partially resistant to Helicoverpa and mites. Using the original Siokra strain, eleven other cultivars have been developed, from which two varieties are transgenic. Subsequently, another major cotton variety, Sicala 3-1, was released by CSIRO in 1987, followed by the release of Sicala V-1 in 1991 and Sicala V-2 in 1994. Sicala varieties have a high degree of resistance to Verticillium wilt, a feature that reduces the spread of the disease in the soil of cotton growing regions. Since 1996, many of these varieties have incorporated a combination of genetically modified features developed by crop breeding companies and used under licence by CSIRO. By 2013/14, approximately 99 per cent of Australia's cotton was transgenic, combining CSIRO's elite germplasm with traits from Monsanto or Bayer. The major variety in 2013/14 was Sicot 74BRF.

#### Australia: a unique and challenging environment for cotton growing

**Australia poses unique challenges to cotton growing**

Although Australia is one of the top four global cotton exporters, its cotton crops are regularly at risk due to a unique mixture of factors that influence cotton production, breeding and management. These factors include:

- climate
- soil
- pests
- disease.

These factors all endanger the future profitability of the Australian cotton industry. Australia's cotton growing region encompass an area from central Queensland extending south to the NSW-Victorian border. The broad geographic spread of cotton growing areas inevitably leads to cotton being grown in areas with different and distinct climates, from generally higher temperatures in the north, to cooler temperatures in the south, generally drier conditions in the west, to wetter conditions in the east (Constable *et al.*, 2001). This wide array often highly variable climatic conditions poses challenges for Australian cotton growers seeking to better adapt cotton seed strains and growing practices to local conditions.

The majority of Australian cotton is grown on alkaline heavy clay soil. This soil is regarded as 'sodic' (or containing high levels of exchangeable sodium), especially in the western and drier locations. This soil has a high water holding capacity and its cracking nature allows for swift refill during irrigation. However, it is prone to soil compaction and waterlogging, which can lead to sharp decreases in crop yield (Constable *et al.*, 2001).

The most damaging pest to Australian cotton production is the Helicoverpa bollworm. It has two species, *H. punctigera* and *H. armigera*, with the latter being particularly renowned for its ability to develop resistance to synthetic pesticides. Helicoverpa is a major challenge for entire seasons in the majority of production areas. In 1974, *H. armigera* developed resistance to pesticides and was responsible for the failure of the entire cotton industry in northern WA. Spider mites are also capable of causing considerable damage to cotton production every season. In addition to these major pests, other pests, such as mirids, aphids, thrips and tip borer, emerge sporadically between seasons and different cotton growing sites (Constable *et al.*, 2001).

Some diseases are widespread in Australia, including bacterial blight and Verticillium wilt, and can cause serious damage to cotton crops. Other notable diseases include Black Root Rot, Alternaria leaf spot and Fusarium wilt. These all pose growing challenges across a range of cotton production regions every season (Constable *et al* 2001).

### C.1.3 Approach

This approach taken in this case study is based on CSIRO's impact framework and aligns with the nine-step process described in the CSIRO's impact evaluation guide, namely:

1. Initial framing of the purpose and audience of the impact evaluation.
2. Identify nature of impacts (*what is the impact pathway, what are the costs and benefits*)
3. Define a realistic counterfactual (*what would have occurred in the absence of CSIRO*)

4. Attribution of research (*CSIRO vs. others' contribution*)
5. Adoption (*to date and in future*)
6. . Impact (*timing, valuation, distributional effects among users, effects on non-users*)
7. Aggregation of research impacts (*within program of work*)
8. Aggregation of impacts (*across program of work*)
9. Sensitivity analysis and reporting.

In quantifying the costs and benefits of CSIRO's cotton research project, this case study examines a limited time period or 2006 to the present. However, it is important to note that CSIRO's cotton varieties research project has delivered substantial benefits over the entire life time of the research project. Our cost-benefit analysis builds upon impressive net benefits delivered between 1973 and 2001 – $5 billion according to a 2002 CIE study – and between 2002 and 2005 – $65 million per annum, according to a 2006 ACIL Tasman study.

The impacts identified in this case study will be aggregated with those from other aspects of CSIRO's work to provide an insight into the overall benefits arising from the Organisation's work.

### C.1.4 Project origins and inputs

CSIRO's work on cotton has been undertaken with the goal to:

> Develop Australian cotton varieties with increased yield; with fibre quality preferred by international spinners; resistance to all important diseases; widely adapted; and with genetically modified traits of interest.
>
> Focus on better breeding and associated research outcomes for Australian cotton.

**CSIRO's cotton research contributes to the Agriculture Flagship goal**

Since the July 2014 restructure of CSIRO, work on cotton now resides within CSIRO's Agriculture Flagship, the goals of which is:

> To deliver transformational positive impact on the productivity, profitability and agro-ecosystem health for Australia's agri-food- and agri-fibre industries and to partner globally towards food security in a resource and climate challenged world. Together with our private and public sector partners we aspire to develop technologies, management and knowledge systems that will, by 2030, raise yield ceilings, close yield gaps and increase production efficiencies to underpin a 30 per cent increase in targeted primary food and fibre productivity and/or eco-efficiency.

The outcomes and impact from CSIRO's work on cotton varieties will make an important contribution to this Flagship goal through increased productivity due to the development of new cotton varieties that provide higher yields while requiring fewer inputs.

Inputs to CSIRO's work on cotton varieties since 2003-04 have been estimated from staff numbers at the Cotton breeding group, Narrabri and some segments of the cotton biotechnology group at the Black Mountain laboratories in Canberra (see Table C1 ).

Table C1 **CSIRO staff working on cotton varieties project**

| Year | Full time equivalents Narrabri | Full time equivalents Black Mountain |
|---|---|---|
| 2003-04 | 13.0 | 6.6 |
| 2004-05 | 13.0 | 6.6 |
| 2005-06 | 13.0 | 6.6 |
| 2006-07 | 16.0 | 6.6 |
| 2007-08 | 15.5 | 6.6 |
| 2008-09 | 19.5 | 6.6 |
| 2009-10 | 20.5 | 6.6 |
| 2010-11 | 22.3 | 6.6 |
| 2011-12 | 23.3 | 6.6 |
| 2012-13 | 24.3 | 6.6 |
| 2013-14 | 24.3 | 6.6 |

Source: CSIRO

**CSIRO works closely with the cotton industry**

Other inputs have come from Cotton Seed Distributors (CSD), a grower-owned and controlled organisation, which markets CSIRO-bred cotton seed and provides specialised support to Australian cotton growers through an in-field team of experienced agronomic staff. CSD has a long term partnership with CSIRO. The Australian government's Cotton Research and Development Corporation (CRDC) also provided funding. CSIRO, CSD and CRDC funding inputs dedicated to the core breeding, core biotechnology and quality assurance programs, as well as the development and use of Fusarium nurseries, are listed in Table C2.

Table C2 **Cotton varieties research project inputs ($ million)**

| Year | CSIRO | CSD | CRDC | Total |
|---|---|---|---|---|
| 2006/07 | 3.004 | 1.202 | 0.367 | **4.573** |
| 2007/08 | 2.996 | 1.493 | 0.390 | **4.878** |
| 2008/09 | 3.32 | 1.691 | 0.000 | **5.010** |
| 2009/10 | 3.842 | 1.471 | 0.000 | **5.313** |
| 2010/11 | 4.238 | 1.542 | 0.000 | **5.780** |
| 2011/12 | 4.577 | 1.430 | 0.000 | **6.006** |
| 2012/13 | 4.750 | 1.469 | 0.000 | **6.218** |
| 2013/14 | 5.472 | 1.579 | 0.000 | **7.051** |
| 2014/15 | 5.642 | 1.611 | 0.000 | **7.252** |
| **Total** | **37.841** | **13.488** | **0.757** | **52.081** |

Source: CSIRO

In the current CSIRO strategy period (2011-15), CSD support to CSIRO's cotton breeding and biotechnology research has been through the Cotton Breeding Australia Joint Venture.

## C.2 Project activities

**CSIRO's cotton R&D is long term and ongoing**

There are a number of notable features of CSIRO's cotton breeding methodology, which have underpinned the success of the project. As noted above, CSIRO work on cotton varieties extends over a number of decades. This long experience in developing varieties to meet the challenges of various pests and diseases has been the essential underpinning of the successful work undertaken more recently. The lead time on developing new cotton varieties is around ten years and each new variety lasts about five years before it is replaced.

CSIRO also establishes strategic targets for its work on cotton and reviews these on a regular basis. Fibre quality targets are based on future spinning industry requirements and CSIRO has instrumentation to accurately measure and screen for all fibre properties of interest. Disease resistance is sought for existing and possible diseases; disease nurseries and bioassays are used to screen for resistance.

Conventional breeding techniques are used with strong emphasis on large population sizes and extensive regional testing of elite lines which are selected in experiments that are designed to ensure confidence in results. A total of 30,000 plots are sown and harvested each season. Breeder seed of candidate commercial varieties is handed over to Cotton Seed Distributors for commercial sale in Australia and worldwide.

In keeping with CSIRO tradition, there is a multidisciplinary cotton team covering plant breeding, biotechnology, agronomy, physiology, pest management and post-harvest processing.

During the current CSIRO strategy period (2011-15) CSIRO has continued to develop new varieties of cotton and undertake related activities. Research activities in this period include work on disease and pest resistance, fibre quality, regional adaptation and application of gene technology.

### C.2.1 Gene technology

**CSIRO's breeding project targets several issues**

Breeding of new varieties relies on genetic diversity. A core activity of CSIRO's cotton varieties project is to source or create diversity of genetic features that influence yield, fibre quality, disease resistance and plant growth patterns that optimise plant size and harvest maturity to match each climate and crop management system. CSIRO is constantly importing novel germplasm through quarantine to evaluate it for use in crossing.

Continued usage of gene technology is expected to accelerate the screening and development of new conventional and transgenic cotton varieties. Research at CSIRO has grown in this area in order to develop and use molecular tools and characteristics to meet production and sustainability goals (CSIRO, 2014).

#### Disease and pest resistance

CSIRO has bred genetically modified (GM) cotton varieties that include insect and herbicide resistance. This has been done by introducing Bollgard® II and Roundup Ready Flex® traits from Monsanto into CSIRO germplasm (CSIRO, 2014). Box C1 outlines the benefits of Bollgard® II.

Box C1 **GM cotton and benefits of Bollgard® II**

Bollgard® II, was developed by Monsanto by introducing two genes from the soil bacterium Bacillus thuringiensis (Bt) into cotton. The effect of these genes is to produce two proteins that are toxic to the primary insect pest of cotton (Helicoverpa caterpillars) which die upon consumption of the Bollgard® II cotton. The adoption of Bollgard® II technology has led to a decrease in insecticide applications by approximately 80 per cent for the entire cotton growing industry.

The Helicoverpa caterpillars are renowned for their ability to destroy entire cotton crops if not managed appropriately. In the past, pesticides were frequently deployed to combat these pests. However, the pesticides were found to be killing beneficial insects in the process. Bollgard® II cotton varieties are advantageous as they only target Helicoverpa caterpillars. In addition, the Bt genes have been tested to confirm that they do not harm human or any other animals. These traits are approved by Australian Regulatory Authorities such as OGTR and APVMA.

Bollgard® II crops have been found to grow at an accelerated rate due to their immunity from insect attacks. Field tests have revealed Bollgard® II varieties have similar or higher cotton yield and fibre quality relative to conventional non-GM cotton varieties. Further trials have indicated that Bollgard® II varieties can be more water efficient.

Sources: CSIRO 2010, and Constable *et al* 2011.

One such issue is disease and pest resistance …

CSIRO research on disease and pest resistance has included progress on the development of cotton varieties that are resistant to Bacterial Blight and Verticillium Wilt (CSIRO 2014). Fusarium Wilt is a particularly destructive, and relatively new, disease to affect cotton in Australia. CSIRO is therefore focusing on ensuring that any new cotton varieties contain resistance to the disease. CSIRO is also developing cotton varieties for resistance to the Cotton Bunchy Top disease, a virus which is transmitted by aphids and causes reduced yields.

#### Fibre quality

… the need for improved yields and fibre quality are others …

CSIRO has used conventional breeding to significantly enhance cotton yield and fibre quality. It intends to develop premium fibre varieties that will enable growers to command higher sale prices through production and sale of a premium product. CSIRO is also using gene technology to assist in the identification of genes that are responsible for fibre development (CSIRO, 2014).

#### Regional adaptation

… varieties tailored to regional conditions is another

In Australia, cotton is grown in a variety of environments under both dry land and irrigated conditions. CSIRO-bred cotton varieties are tailored to the conditions of each region in order to augment performance. The characteristics to suit the ‘central’, ‘hot’ and ‘cool’ regions of Australia’s cotton growing areas include:

- high yield and water use efficiency
- heat and stress resilience
- disease resistance
- maturity to match the length of the season (CSIRO, 2014).

### C.2.2 Research through the value chain

CSIRO conducts research relevant to the entire cotton value chain

In addition to the genetic breeding of cotton varieties for seed supply, CSIRO is researching improved cotton crop management techniques, water management, pest management techniques, and post-harvest handling and management. CSIRO also collaborates with the Australian Cotton Shippers Association and the International Textile Manufacturers Federation on initiatives to improve post-harvest transportation and handling with the aim of ensuring that damage to, or contamination of, high quality cotton fibre is minimised (CSIRO 2008, 2009). CSIRO maintains post-harvest researchers at Geelong and Narrabri. As a result of these additional activities, CSIRO has a research presence through the cotton growing and production value chain, enhancing the benefits gained from its core cotton varieties breeding project.

The necessary skills and expertise are drawn from across CSIRO

Work on this project utilised a wide range of CSIRO's skills and expertise. Table C3, below, lists the key capabilities and summarises the activities undertaken for each of those capabilities.

Table C3 **Key CSIRO capabilities used in cotton varieties project**

| CSIRO capability | Activity |
|---|---|
| **Quantitative genetics** | Review literature and develop local genetic populations with diversity in characteristics of interest, especially yield and disease resistance. Continually import germplasm from overseas and exchange germplasm where possible to maximise genetic diversity in our own collection. |
| **Cotton breeding methods** | Understand history and literature on different breeding methods. Constantly review and assess alternatives to optimise the breeding timeline while achieving continual genetic improvement in yield, disease resistance, fibre quality and regional adaptation. |
| **Molecular screening** | Research and develop screening tools to use during introgression (a process by which the genes of one variety are integrated into the genes of another) of new traits into elite CSIRO germplasm. Collaborate with trait provider when required. |
| **Regulatory requirements for GM crops** | Liaison with the Office of the Gene Technology Regulator (OGTR) in field practices with GM crops. Research on appropriate pollen traps for preventing gene flow from research plots into commercial crops. |
| **Variety development – disease resistance** | Research in sources of resistance and methods of screening breeding populations for all diseases (present and future). Identification of field sites to use as field nurseries and development of screening measures for Fusarium wilt and Verticillium wilt in particular. When possible, liaise with Canberra molecular group to develop molecular markers to use in screening disease resistance. |
| **Variety development – fibre quality** | Identify present and future requirements for fibre properties and screen breeding populations for compliance with those properties. Research strategies to overcome negative associations between yield and fibre quality. |
| **Statistical design and analysis** | Research and develop field testing procedures across a number of different seasons, sites and replicates to ensure most accurate results are obtained for data on new breeding lines. Understand interaction between different seasons and sites so that specific or broad regional adaptation can be identified. |
| **Project management** | Management of individual components and coordination of Narrabri and Canberra teams to maximise synergy. Liaison with commercial partner, CSD, to match breeding and commercial strategies and to provide breeder seed of elite lines for seed increase and marketing. |

*Note:* Only the key CSIRO capabilities are listed in the above.
Source: CSIRO

## C.3 Project outputs

### C.3.1 Key outputs of the project

CSIRO bred cotton varieties now dominate the market

The research project outputs consist of new cotton varieties that provide increased yield, enhanced pest resistance and are adapted to the regions in which they are grown, while using less water. Over the past 30 years, CSIRO has released a total of 102 cotton varieties (see Table C4). Since 2000, some of CSIRO's top selling transgenic cotton varieties have been Sicot 71BR (which accounted for 50 per cent of transgenic cotton market share between 2005 and 2007, measured as percentage of the total area sown with transgenic cotton seeds), Sicot 71BRF, which peaked between 2008 and 2010 at above 80 per cent market share, and Sicot 74BRF, which rose to over 70 per cent of market share in 2013 and remains the dominant selling variety.

Table C4 **CSIRO cotton varieties, 1983 - present**

| Conventional | | | Transgenic | | | |
|---|---|---|---|---|---|---|
| Sicot 1 | CS 7S | Sicot 70 | Siokra V-15i | Sicala 40RRi | Sicala 40BR | Sicot 43BRF |
| Sicot 3 | CS 50 | Sicot 72 | Siokra L-23i | Sicot 289RRi | Sicot 289B | Sicot 80RRF |
| Siokra 1-1 | Siokra L23 | Sicot 80 | Sicala V-2i | Siokra V-16RRi | Sicot 80B | Sicot 43RRF |
| Siokra 1-2 | CS 189+ | Siokra S-102 | Sicot 50i | Siokra V-17i | Siokra V-18B | Sicot 70BRF |
| Sicala 3-1 | Siokra V-15 | Sicala 43 | Sicot S-8i | Sicot 11B | Sicala 40B | Sicot F-1B |
| Siokra 1-4 | Sicala V-2 | Sicot 71 | Sicot 189i | Sicot 12B | Siokra V-16B | Sicala 45B |
| Sicala 3-2 | CS 8S | Sicala 45 | Sicot 289i | Sicot 13B | Sicot 71B | Sicot 80L |
| Sicala 33 | Siokra S-101 | Siokra V-18 | Siokra V-16i | Sicot 14B | Sicot 71RR | Sicot 43L |
| Siokra S324 | Sicot 189 | Sicot F-1 | Sicot 189RR | Sicot 289RR | Sicot 43BR | Sicot 71BRF |
| Siokra L22 | Siokra V-16 | Sicot 73 | Sicala V-2RR | Sicot 60RR | Sicot 43B | Sicot 71RRF |
| CS 6S | Sicala 40 | Siokra 24 | Sicala V-3i | Sicot 289BR | Sicot 43RR | Sicot 74BRF |
| CS 189 | Sicot 53 | Sipima 280 | Sicala V-3RRi | Sicot 71BR | Sicot 80RR | Sicot 70BL |
| Sicala V-1 | Siokra V-17 | Sicot 75 | Siokra 201i | Sicala 60BR | Sicala 350B | Sicala 340BRF |
| Sicala 34 | | Sicot 730 | Sicot 42i | Sicala V-3BR | Sicala 60BRF | Sicot 75BRF |
| | | | Sicala 40i | Siokra V-16BR | Sicot 80BRF | Siokra V-18BL |
| | | | | | | Sicot 75RRF |

Source: CSIRO

## C.3.2 Key Publications

Over the past 14 years CSIRO has published in excess of 40 scientific journal articles and a number of refereed conference papers of relevance to cotton variety development. Examples of some of the papers with the greatest impact in the field are provided below:

- Constable, G.A., Thomson, N.J. and Reid, P.E. (2001). Approaches utilized in breeding and development of cotton cultivars in Australia. In: Genetic Improvement of Cotton: Emerging Technologies. JN Jenkins and S Saha (Eds.). Science Publishers, Enfield. pp 1-15
- Stiller, WN, Reid, PE and Constable, GA (2006). Lessons learnt in developing transgenic cotton (*Gossypium hirsutum*) varieties. In: C.F. Mercer (ed.). Breeding for Success: Diversity in Action. Proceedings of the 13th Australasian Plant Breeding Conference, Christchurch, New Zealand 18-21 April 2006. pp. 56-61
- Constable, G., Llewellyn, D., Wilson, L. and Stiller, W. (2011). An industry transformed: the impact of GM technology on Australian cotton production. Farm Policy J. 8, 23-41
- Stiller, W.N., Constable, G.A. and Reid, P.E. (2009) Resistance to the new Australian strain of fusarium wilt among non-cultivated *Gossypium*. *SABRAO Journal of Breeding and Genetics* VOL. 41 Special Supplement August 2009
- Constable, GA. (2009). Breeding as a business - return on R&D investment in crop improvement. 14th Australasian Plant Breeding Conference and 11th SABRAO Congress, Cairns, 2009. Invited plenary speaker
- Liu, SM, Constable, GA, Reid, PE, Stiller, WN and Cullis, BR. (2013). The interaction between breeding and crop management in improved cotton yield. Field Crops Res. 148, 149-160

### C.3.3 Awards and public recognition

The CSIRO cotton breeding project and team have received a range of honours for their contribution to Australia. These awards and recognition are outlined in Table C5.

Table C5 **Awards**

| Award | Year | Team members |
|---|---|---|
| CSIRO Chairman's Medal | 2003 and 2011 | ▪ Greg Constable and Danny Llewellyn (2003)<br>▪ Greg Constable, Danny Llewellyn, Warwick Stiller, Shiming Liu, Peter Reid and technical staff (2011) |
| Clunies Ross Award | 2006 | ▪ Greg Constable<br>▪ Danny Llewellyn<br>▪ Gary Fitt |
| Sir Ian McLennan Achievement for Industry Award | 1989 and 2004 | ▪ Norm Thomson (1989)<br>▪ Peter Reid (2004) |
| Centenary Medal | 2001 | ▪ Greg Constable<br>▪ Danny Llewellyn |

Source: CSIRO

## C.4 Status of Outcomes and Impacts

### C.4.1 Nature of Outcomes and Impacts

#### Outcomes

The primary outcome of CSIRO's cotton varieties project is the development new products – cotton seed varieties – through a process of genetic breeding. This process has yielded five key outcomes:

**CSIRO's primary outputs have been improved cotton varieties**

— *Increased cotton yield through application of genetic breeding*. Uptake of CSIRO-bred cotton varieties has led to significant increases in cotton yield per hectare as a result of both reduced crop losses due to disease and pests and greater adaptation of cotton varieties to specific local conditions.

— *Disease and pest resistance*. CSIRO has developed cotton varieties with enhanced disease resistance in order to fight serious diseases. Notable progress has been attained in developing cotton varieties that are resistant to Bacterial Blight and Verticillium Wilt in particular (CSIRO, 2014). Pesticide use has decreased by up to 80 percent amongst insect resistant Bollgard® II varieties (CSIRO, 2014).

— *High fibre quality*. CSIRO's cotton breeding project has resulted in improvements in fibre length and micronaire, which has improved Australia's reputation amongst international spinners as a source of high-quality cotton. Data from the Australian Cotton Shippers Association demonstrates significant increases in the uniformity of exported Australian cotton quality and average staple length (with a longer staple indicating longer fibres and greater spinning value) (Australian Cotton Shippers Association, n.d.).

— *Regional adaptability*. CSIRO has successfully bred a range of cotton varieties that are adapted to Australia's diverse soil and climatic conditions, including the effects of heat stress. As a result, the area over which cotton growing takes place in Australia has spread into the Darling Downs in south-east Queensland and north into central Queensland. Without CSIRO's cotton varieties bred to heat stress tolerance and Australian pests and diseases, cotton growing in these areas would have not been commercially viable.

— *Water efficiency*. Australian cotton crops use on average 40 per cent less water in producing a bale of cotton than they did 10 years ago (Roth *et al.* 2013). This overall increase in water efficiency has arisen out of a combination of new cotton varieties developed by CSIRO as well as improvements in water and crop management.

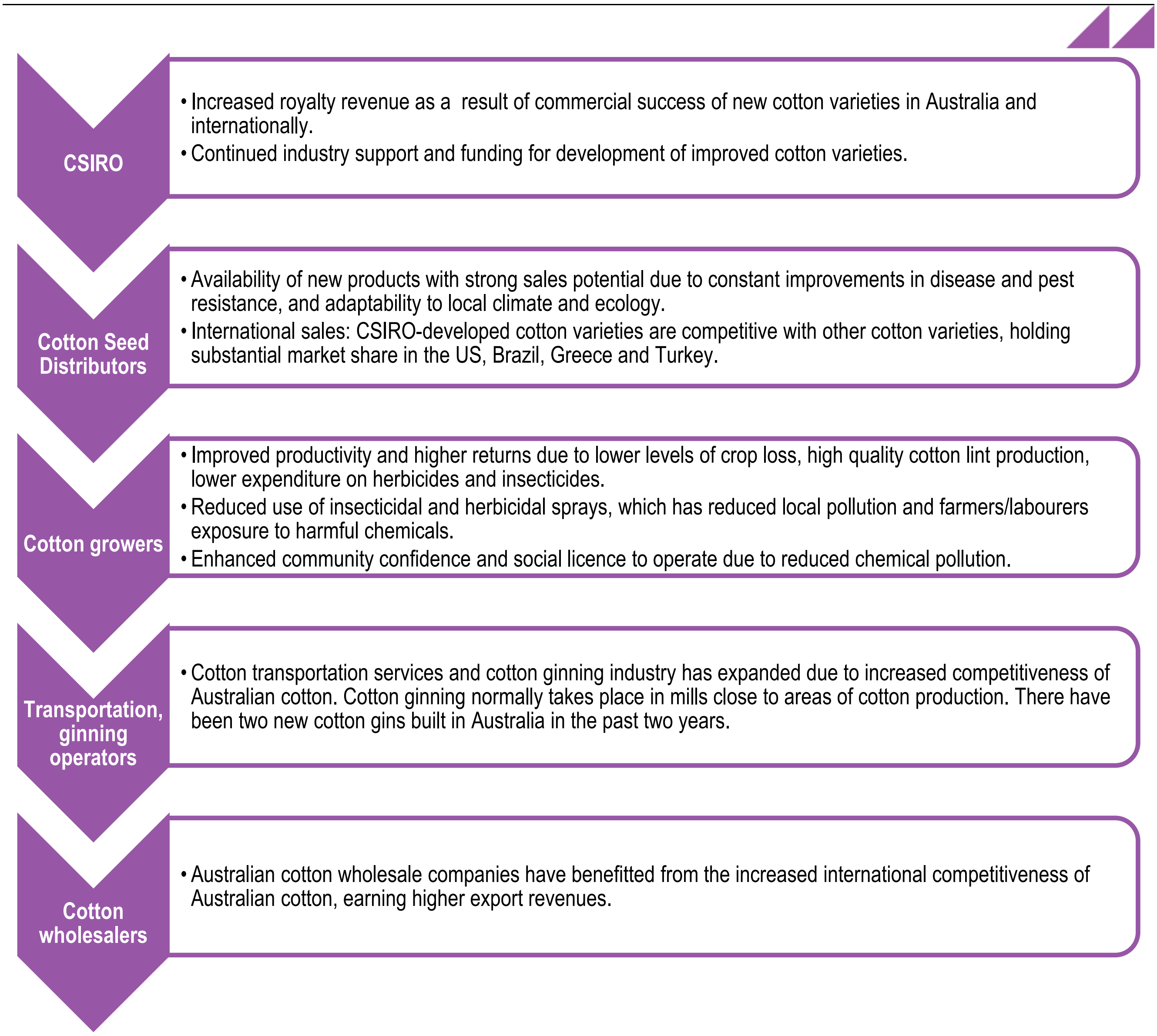
**The benefits of the new varieties have driven rapid uptake**

CSIRO's success in achieving these research outcomes has been borne out by the strong market uptake of CSIRO-bred cotton varieties: CSIRO cotton varieties now account for 100 per cent of cotton seeds sold in Australia, and export sales to countries such as the United States, Turkey, Brazil and Greece have been strong.

Currently CSIRO is trialling an update to Bollgard® II to assure no resistance develops to Bt. This new trait is being introduced into elite CSIRO varieties for possible commercial release in 2016.

Aside from the development of new cotton varieties, CSIRO's research has also yielded outcomes through the cotton production value chain from seed distributors to downstream processors, as outlined in Figure C2.

Figure C2 **Outcomes and impacts of new cotton varieties through the cotton production value chain**




Source: ACIL Allen Consulting; CSIRO

### Impacts

Table C6 summarises the outcomes and impacts to date of CSIRO's cotton varieties research project.

Table C6 **Market and non-market impacts from CSIRO's cotton research**

| Impact | Detail |
|---|---|
| **Environmental impact category** | |
| Reduced chemical contamination from insecticidal sprays<br>Category: sustainable industry development<br>Reach: industry | Cotton varieties utilising Bollgard® II had led to a roughly 80 per cent decrease in pesticide use across Australia. Varieties utilising Roundup Ready Flex® have led to a 52 per cent decrease in residual herbicide use (CSIRO, 2014). This has resulted in improved water, soil and air quality in cotton growing regions and lower levels of environmental pollution (Knox *et al.*, 2006). |
| Increased water use efficiency<br>Category: water quality and management<br>Reach: industry | CSIRO varieties have significantly increased water use efficiency of cotton growing in Australia. Over the past decade water use efficiency in cotton farming has improved by 40 per cent due to a combination of changed water management and CSIRO's new, water-efficient cotton varieties (Roth *et al.* 2013). |
| **Social impact category** | |
| Improved quality of life & health<br>Category: life and health<br>Reach: industry | A reduced dependency on aerial spraying of pesticides has led to reduced interaction with harmful chemicals for farmers, labourers and local communities (Knox *et al.*, 2006). |
| Social licence to operate and community confidence<br>Category: social license to operate community confidence<br>Reach: industry | Farmers who grow CSIRO cotton varieties can lessen public concerns over environmental damage or health impacts from aerial pesticide spraying near towns by generally avoiding this practice. |
| Increased sustainability of rural communities<br>Category: resilience<br>Reach: industry | Cotton underpins the economy of rural areas in which it is grown, providing income for farmers, labourers, cotton transportation workers and cotton ginning workers. The cotton industry also support local economic activity by supporting secondary industries and services. |
| **Economic impact category** | |
| Increased productivity of cotton growing<br>Category: management and productivity<br>Reach: industry | ▪ Reduced crop loss as a result of disease and pest attacks means higher yield of usable cotton and lower expenditure on pesticides and herbicides.<br>▪ Reduced crop damage due to pest and disease attacks yields higher quality cotton, which commands a price premium on the market.<br>▪ Expanded area over which cotton farming is viable: from 2005 to 2013, an average 24 per cent of the area of cotton grown in Australia annually was due to CSIRO's new cotton varieties, according to data supplied by CSIRO.<br>▪ Average 15 per cent increase in productivity (measured as cotton produced/hectare) from 2006/7 to 20013/14, after adjustments for year-to-year production volatility. |
| Increased international trade<br>Category: international trade<br>Reach: industry | ▪ Increased competitiveness of cotton exports due to increased productivity of Australian cotton farming and production of higher quality lint. Total export value of $2.7 billion in 2012-13.<br>▪ Increased export of CSIRO-developed cotton cultivars due to suitability for use in countries such as Brazil, the US, Greece and Turkey and the competitiveness of Australian cotton varieties against major international seed suppliers. |
| Employment, contribution to GDP<br>Category: the macro economy<br>Reach: industry | Increased economic activity and employment as a result of expansion of cotton growing areas and greater productivity. In the 2011 national census, 1,740 people self-identified as being employed in the cotton growing industry, a figure that would not include additional employment in downstream cotton transportation and processing industries as a result of increased productivity further upstream. |

Source: ACIL Allen Consulting

## C.4.2 Counterfactual

Australia's cotton growing industry would have suffered losses in productivity from 2006 to the present (the time period of the following cost-benefit analysis), had CSIRO's work on cotton varieties not continued.

## CSIRO impact and counterfactual prior to 2006

Prior to 2006, CSIRO had already delivered significant benefits to the Australian cotton industry. These benefits formed the foundation for continued improvement post-2006 (the analysis period of this case study and cost-benefit analysis). The fragmented nature of cotton breeding programs across Australia in the 1960s and 1970s prevented the development of a strategic approach to research and breeding. CSIRO was instrumental in uniting disparate breeding programs and for establishing a cohesive approach to cotton research and breeding in Australia.

**Without CSIRO's R&D the cotton industry in Australia would be less significant**

In the absence of CSIRO work on cotton over the past several decades, Australia would have seen:

- *Continued reliance on US cotton varieties.* These varieties are mainly tailored to US conditions and do not provide resistance to cotton diseases found in Australia such as bacterial blight and Verticillium wilt.
- *Continued reliance on pesticides.* By adapting Monsanto technology focused on Helicoverpa resistance to Australian growing conditions, CSIRO enabled Monsanto technology to be applied more widely and effectively in Australia, reducing the need for chemical pesticide spraying. While Bollgard® was available from other seed suppliers, CSIRO's superior overall germplasm strengthened the uptake of this new gene technology. By reducing the frequency of pesticide sprays, CSIRO cotton varieties have also reduced the prospect that common pests will develop resistance to insecticides (CIE 2002).
- *Reduced yields*. Yields from CSIRO cultivars have shown an average increase of 23 kilograms of lint per hectare annually. In comparison, yields from US cultivars (which were available in Australia until 1998) show that although they showed an average increase of only 13 kilograms of lint per hectare annually, or approximately 45 per cent less relative to CSIRO's breeding activities (CIE, 2002). Moreover, the expansion of cotton growing into new regions in Australia, such as Darling Downs (in Queensland), and the Upper Namoi, Hillston and MIA regions (in NSW), would have been unlikely, had Australia continued to rely on US cotton varieties (CIE, 2002). Estimates suggest that approximately 30 per cent of the expansion in the area of cotton planted between 1983 and 2001 was largely due to the CSIRO breeding project (CIE, 2002).
- *A likely decline of the cotton industry relative to its present strength and size*.

## CSIRO impact and counterfactual post-2006

**CSIRO's cotton research continues to deliver benefits**

In the period 2006 to the present, CSIRO's cotton varieties have continued to deliver significant yield increases. From 2006/7 to 20013/14, average productivity of Australian cotton production increased by approximately 15 per cent according to CSIRO data, after adjustments for year-to-year production volatility due to climatic factors (see Figure C6). Given that CSIRO cotton varieties accounted for over 90 per cent of cotton seeds sold in Australia by 2005 and 100 per cent of seeds sold by 2009, these increases in yields would likely not have taken place absent CSIRO.

Increased productivity of cotton farming has also generated income for growers and additional employment in related industries such as retail, service, ginning and transporting. These additional economic gains would have been foregone in the absence of ongoing CSIRO research into cotton varieties post-2006.

Advancements in Australian cotton varieties have led to high demand for CSIRO varieties on the global spinning market. A recent Deakin University and CSIRO study (SG Gordon and D Mallick, unpublished) has identified that international demand for Australian cotton is relatively inelastic, meaning that the price drops little when the volume marketed increases, because there is large pent up demand from international spinners for higher quality cotton. Without CSIRO's research into enhancing cotton yield and fibre quality, Australian growers would have faced reduced access to these premium markets and would have foregone international market share to major competitors such as the US, Pakistan, India and Brazil.

The unique characteristics of CSIRO cotton varieties such as its regional adaptation capabilities have led to strong demand for CSIRO cotton varieties seeds in international markets. In association with Cotton Seed International and Bayer, CSIRO developed varieties are marketed as FiberMax cotton in overseas markets (CIE, 2002). This has resulted in a flow of licensing fees to CSIRO from the international sale of seed which would otherwise not have occurred.

However, it is notable that two of the largest benefits of CSIRO's cotton varieties research, reduction in pesticide use and increased water efficiency, took place largely prior to 2006. By 2006, pesticide use in cotton growing was greatly reduced, currently sitting at around 0.2g per kg of cotton lint produced. While CSIRO continues to make progress in breeding new cotton varieties for disease and pest resistance (which brings the benefit of increased lint yield), the largest reductions in pesticide use took place largely prior to our cost-benefit analysis period of 2006-the present. Similarly, data from Cotton Australia indicates that water use efficiency has largely flattened out at 2.5 ML per tonne of cotton produced since 2008, after large decreases in water usage per tonne of cotton produced in the preceding years.

#### Other international cotton research programs

**CSIRO's cotton research is unique in the world**

No other organisation in the world has been able to replicate CSIRO's level of cotton research coordination, particularly in terms of the degree to which CSIRO has been able to use its unique research structure to create nationally beneficial research outcomes. Australian cotton industry benefits from a highly integrated system of research into cotton breeding and management. Other countries have been unable to replicate this system due to the absence of Australia's strategic approach. In the USA, for example, numerous universities and private companies employ unique breeding projects for their local environments. However, these breeding projects are not connected to a larger strategic program; therefore they are not effective for a broader range of environments across the USA.

### C.4.3 Attribution

**100% of the outcomes of research into new cotton varieties since 2006 can be attributed to CSIRO**

CSIRO was the primary source of research, breeding expertise and resources that underpinned the development of new cotton varieties. Other contributors to the successful implementation of CSIRO research include Cotton Seed Distributors Ltd, the Cotton Research and Development Corporation, and Australia's cotton growers. Cotton Research and Development Corporation provided important co-financing for CSIRO's cotton varieties project from 1990 to 2008 and the Cotton Seed Distributors provided important co-financing from 2006 to the present. Cotton growers have also played an important role in CSIRO's development of new cotton varieties by providing sites for testing of breeding material. However, these organisations and growers have not actively taken part in the research and development of these new varieties.

Monsanto has provided some of the base technology for resistance to pesticides, which has aided management of Helicoverpa pests and facilitated easier crop management for new growers, particularly in Southern regions. Some of the impact of reduced pesticide use can therefore be attributed to Monsanto. However, increases in yields have been primarily due to the development of CSIRO cotton varieties. As 100 per cent of Australian cotton is currently grown from CSIRO cotton varieties, 100 per cent of the impact of breeding on yield productivity can be attributed to CSIRO.

**60 per cent of Australia's increased cotton productivity can be attributed to CSIRO.**

In their survey of 15 irrigated farm trials, Liu *et al* (2013) found that yield gain from CSIRO's cotton work can be attributed to genetics (48 per cent), management (28 per cent) and the interaction between genetics and management (24 per cent). Given that 100 per cent of cotton seeds sold in Australia have been CSIRO-bred varieties from 2009 (see Section C.4.4), and given that 100 per cent of the post-2006 research outcomes of the cotton varieties project are attributable to CSIRO, roughly 60 per cent of increased cotton productivity in Australia can be attributed to breeding of new cotton varieties by CSIRO.

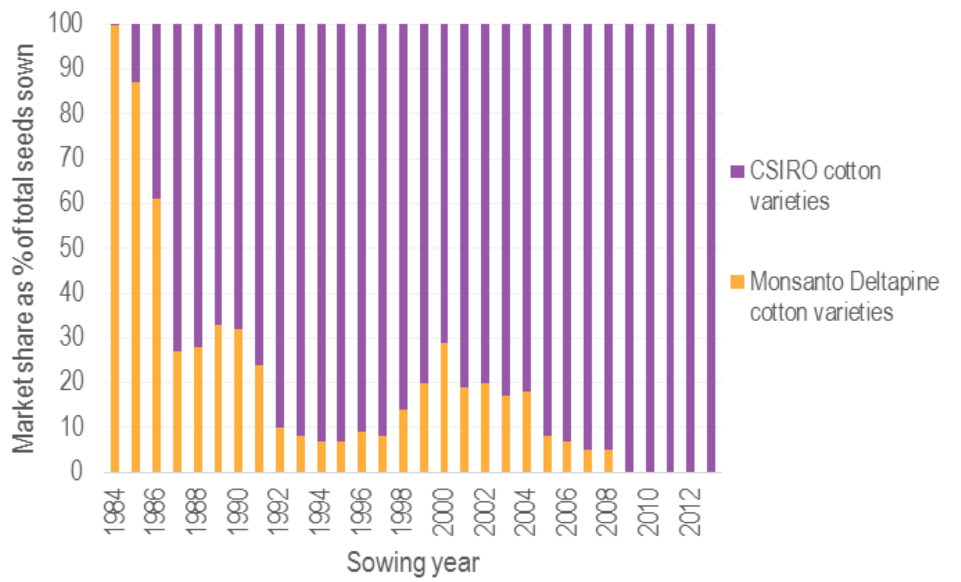
## C.4.4 Adoption

### Adoption rates

**The adoption rate of CSIRO varieties in Australia is 100%**

Australia's entire cotton crop is now grown from CSIRO-bred varieties (see Figure C3). CSIRO-bred varieties are also highly sought after in global markets. CSIRO-bred cotton varieties currently represent approximately 25 per cent of varieties sold in the USA and 30-40 per cent of cotton varieties sold in Greece, Turkey and Brazil. The adoption of CSIRO-bred varieties in global markets is expected to continue to increase.

Figure C3 **Adoption of CSIRO cotton varieties versus US varieties in Australia – percent of cotton seeds sown**




Source: ACIL Allen Consulting; CSIRO

### Barriers to uptake

The share of CSIRO-bred cotton varieties in the Australian market is expected to continue to remain at or close to 100 per cent of market share going forward. While the use of GM seeds and the water intensity of the cotton industry have been a source of public concern in the past, these two issues are unlikely to affect continued uptake of CSIRO cotton varieties.

The merits and potential dangers of genetically modified food and agriculture has been regularly debated, particularly in the mid-1990s. However cotton has been largely omitted from this debate as it is not a food crop. As a result, the usage of genetically modified cotton seeds has not faced the resistance that it has in other food cropping industries.

In the past, the high levels of water consumption involved in cotton growing has been a major source of public criticism of the cotton industry, particularly given that many areas of cotton production are prone to drought. However, given that CSIRO's cotton varieties have already delivered significant increases in water efficiency, the use of these varieties has had the effect of mitigating this important barrier to uptake of cotton farming, making cotton farming less water-intensive and more sustainable.

## C.5 Assessment of impacts

### C.5.1 Impacts to date

**CSIRO's cotton breeding project has delivered benefits, including:**

The CSIRO cotton breeding project led to a range of impacts across Australia's cotton-production value chain. These impacts have taken place gradually over the several decades-long lifespan of CSIRO's cotton research. Some of the impacts described below, while very important to highlight, nonetheless took place prior to the assessment period of 2006 to the present. Other impacts of CSIRO's cotton research project have continued to deliver strong gains into the current period.

#### Environmental impacts

**reduced chemical contamination of the natural environment**

***Reduced chemical contamination from insecticidal sprays***

Uptake of CSIRO cotton varieties has resulted in lower use of aerial insecticidal sprays, reducing chemical contamination of local air, soil and water. A study by Knox *et al.* published in 2006 indicated that use of cotton varieties incorporating Bollgard® II technology reduced the environmental impact value of pesticide spraying by an average of 77 per cent compared to conventional cotton varieties over the first two seasons of its use (Knox *et al.*, 2006). Pesticide detections in rivers in the northern Murray Darling Basin have dropped significantly since monitoring began in 1991, particularly those pesticides most commonly used in cotton growing, such as endosulfan, fluometuron and prometryn (Mawhinney, 2012). For example, detections of endosulfan have dropped from appearing in an average of 58 per cent of water samples taken in rivers of the northern Murray-Darling by the NSW Office of Water in the years 1991-2000, to appearing in an average 6.1 per cent of water samples in the years 2000-2007. By contrast other pesticides commonly used in broadacre cropping, but not used in cotton cropping, such as atrazine and simazine, have not displayed such a large drop in detection frequency in the Office of Water's northern Murray-Darling water quality testing, suggesting that pesticides associated with cotton farming have dropped more rapidly compared to other farming activities (Mawhinney 2012).

However, while this is an important impact of CSIRO's project overall, most of the gains in pesticide use reductions took place prior to the analysis period (2006-present) that is the focus of this case study and the cost-benefit analysis.

***Increased water efficiency***

**Increased water use efficiency**

CSIRO varieties have significantly increased water use efficiency of cotton growing in Australia. Over the past decade water use efficiency in cotton farming has improved by 40 per cent due to a combination of changed water management and CSIRO's new, water-efficient cotton varieties (Roth *et al.*, 2013). One study that compared Bollgard® II cultivars and non-BT cultivars with the same genetic background showed an 8 per cent increase in overall water efficiency (Yeates *et al.* cited in Roth *et al.*, 2013). Increased water efficiency has important environmental benefits because it enables increased cotton production while minimising the harm that increased production causes in terms of reduced environmental flows for natural ecosystems. Increases in water efficiency also has positive economic impacts: the International Cotton Advisory Committee has found that Australian irrigation costs are amongst the highest in the world. In 2010, irrigation costs represented an average 8 per cent of the total cost of production in Australia, compared with the USA at 3 per cent (Roth *et al.*, 2013).

However, as with pesticide use, most of the gains in water use efficiency took place prior to the analysis period of this case study and cost-benefit analysis.

## Social impacts

### *Social licence to operate*

– **Reduced community concerns and greater acceptance of cotton farming**

Historically, the cotton industry has drawn considerable criticism within Australia for high levels of pesticide use and high water intensity of cotton growing. Advances in water efficiency and reduction in pesticide use as a result of CSIRO's GM cotton varieties had substantially mitigated wider community concerns over the negative environmental and health impacts of pesticide and water use, strengthening cotton farmers' social licence to operate (ACIL Tasman, 2006).

### *Increased sustainability of rural communities*

Interviews with cotton breeding project members identified a number of other spill over benefits occurring in Australian townships where cotton is grown, particularly in terms of increased employment of farm labourers and local economic activity, as a result of the increased financial sustainability of cotton farms using new cotton varieties.

### *Improved quality of life & health*

Lower use of strong pesticides has reduced the exposure of farmers and local communities in cotton-growing areas to chemicals from aerial spraying. It has also reduced chemical contamination of local air, water and soil. Repeated and regular exposure to some pesticides has been associated with the onset of disease. For example, regular exposure to organophosphates has been linked to with chronic neurological diseases such as Parkinson's disease (National Centre for Farmer Health, 2014).

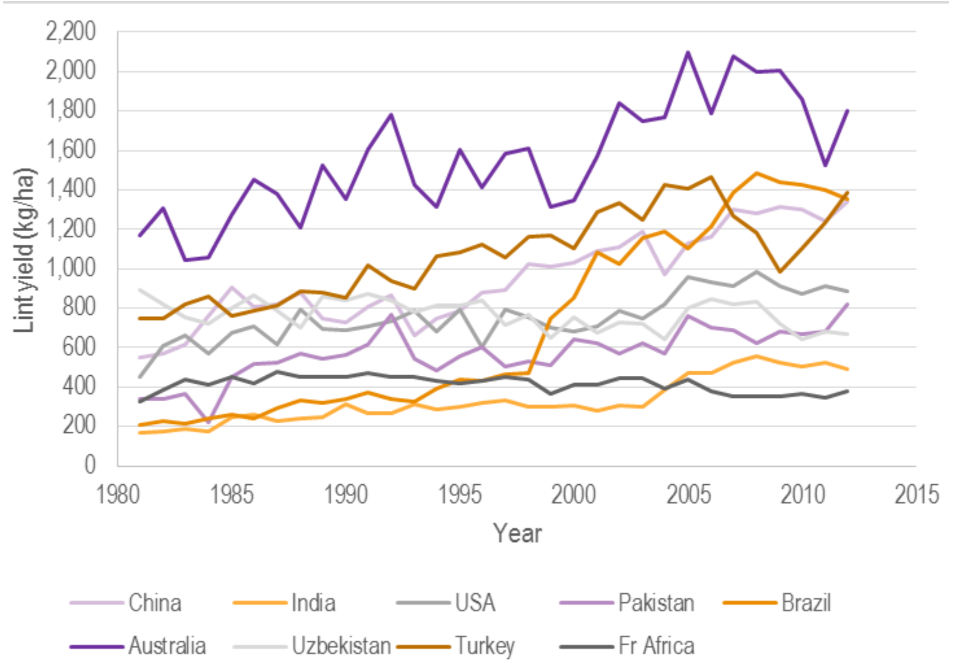
## Economic impacts

### *Increased cotton growing productivity*

**Increased productivity of Australian cotton growing**

CSIRO-bred cotton varieties have increased Australian cotton farmers' productivity by increasing yield, reducing crop loss due to disease and expanding the area over which cotton can be profitably grown in Australia. Between 1967/68 and 1983/84, average annual cotton yields stood at 1.052 tonnes of lint per hectare. Between 1984/85, when CSIRO released its first Siokra cotton strain, and 2012/13, average annual yields have been 1.725 tonnes of lint per hectare. Between 2003/2004, when CSIRO released cotton strains incorporating Bollgard® II technology, and 2012/13 productivity increased to average annual yields of 2.051 tonnes lint/hectare, almost double the productivity rates during the 1960s, 70s and early 80s (ABARES, 2013). Australia's cotton growing productivity measured in terms of kg of lint yield per hectare, is the highest in the world (see Figure C4).

Figure C4 **Cotton growing productivity – Australia and international competitors**




Source: CSIRO

Improvements in lint yield per hectare are due to a combination of both the commercialisation of CSIRO's cotton varieties and changes in farm management. A recent study by Liu *et al*. based on 15 irrigated farm trials per year over the period 1980 to 2009 suggested that 48 per cent of the increased average yield in the trial plots was due to breeding of new cotton varieties, 28 per cent of increased average yield was due to new farming and crop management practices, and 24 per cent of the increased average yield was due to the combination of new cotton cultivars and farm management (Liu *et al.*, 2013). Given that CSIRO cotton varieties accounted by 100 per cent of cotton seeds sold in Australia by 2009, this suggests that roughly 60 per cent of recent gains in cotton growing productivity in Australia can be attributed to CSIRO's cotton varieties breeding project.

**New varieties have enabled the expansion of area under cotton cultivation**

These productivity benefits have been magnified by the expansion of the cotton industry into areas that would otherwise have been unsuitable for cotton growing (due to extremes of hot or cold and/or increased presence of diseases and pests), as a result of CSIRO's climate-adapted cotton varieties. From 2005 to 2013, an average 24 per cent of the area of cotton grown in Australia annually has been due to CSIRO's new cotton varieties and the extra regional adaptability that these cotton varieties afford, according to data supplied by CSIRO.

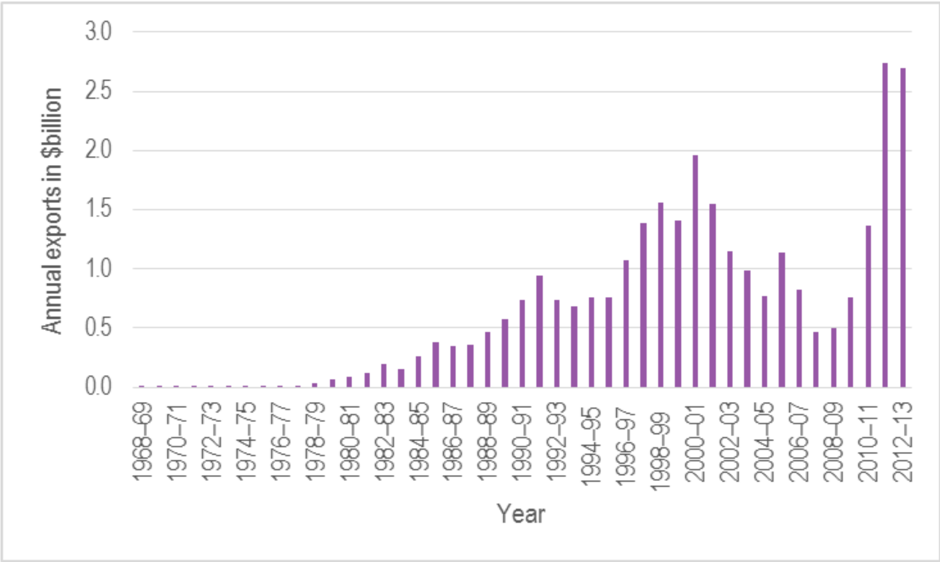
In addition, increased cotton lint yield has led to increased revenues from 'fuzzy seed'. Fuzzy seed refers to the process by which cotton seeds picked up in lint harvesting machines are separated out by cotton ginners (i.e. downstream processors of the lint) and either sold as feed for livestock or sold to cotton seed oil producers. Part of the revenues from the sale of fuzzy seed by cotton ginners are passed back to the cotton farmer that supplied the fuzzy seed. CSIRO estimates that the average value of fuzzy seed is equal to roughly 10 per cent of the revenue from the sale of cotton lint (CSIRO, 2014).

**CSIRO has enabled increased cotton production and exports**

### *Increased international exports*

Improved productivity and cost effectiveness of cotton production in Australia, as well as the high quality of cotton lint from new cotton varieties has been an important driver behind increased cotton exports, the value of which stood at roughly $2.7 billion in 2012-13.

Figure C5 **Australia's annual cotton exports**




Source: ABARES 2013

Apart from Australian-grown cotton, CSIRO-developed cotton strains have also become an important export commodity. CSIRO-developed cotton strains have proven to be competitive against seed suppliers in the international market, with strong uptake in countries such as the US (just above 25 per cent of cotton varieties sown in 2013, up from 2 per cent in 2000) as well as Brazil, Greece and Turkey (30-40 per cent of cotton varieties sown).

***Employment, contribution to GDP***

**New cotton varieties are likely to have contributed to increased employment in cotton industries**

In the 2011 national census, 1,740 people self-identified as being employed in the cotton growing industry. CSIRO cotton varieties now account for 100 per cent of the cotton grown in Australia. These new varieties are likely to have contributed to Australia maintaining its competitive advantage (in terms of lint production per hectare) over other international producers. It is therefore likely that CSIRO's cotton varieties have therefore contributed to maintaining on-farm employment levels.

By the same token, the employment benefits of higher-yield cotton varieties are likely to extend down the cotton production value chain. The expansion of Australia's cotton farming industry has flow on effects for employment in downstream services such as transport and cotton ginning. It is also likely to have boosted secondary industries, such as farm equipment manufacturers and farm suppliers, and the retail sector providing goods and services in cotton growing areas to a certain extent.

## C.5.2 Potential future impacts

**Current research seeks to extend the existing benefits and explore new opportunities to innovate**

Ongoing research will continue to build upon the gains of the last 30 years of cotton breeding to continue to provide cotton varieties with greater disease and pest resistance, including resistance to new threats. For example, since 2009 CSIRO's cotton breeding project has been introgressing Bollgard® III into CSIRO germplasm, which is designed to enhance resistance to Helicoverpa. Release is scheduled for about 2016, depending on regulatory approval. Ongoing research will also focus on production of higher quality cotton fibre, greater adaptability of cotton strains to climatic variability, and improved water efficiency. Based on the success of CSIRO's work on cotton varieties breeding so far and current 100 per cent adoption rate in Australia, this further research can be expected to continue to improve the productivity and competitiveness of Australian cotton.

In addition, CSIRO is pursuing research outcomes in new areas of innovation. A number of sub-projects are focused on improvements in nutrition, seedling vigour and genetic material to produce cotton that requires less energy in ginning. These ideas will flow into new varieties and have potential high commercial impact.

### C.5.3 Cost Benefit Analysis

**Benefits of CSIRO's cotton research are around $150 million between 2006/07 and 2013/14**

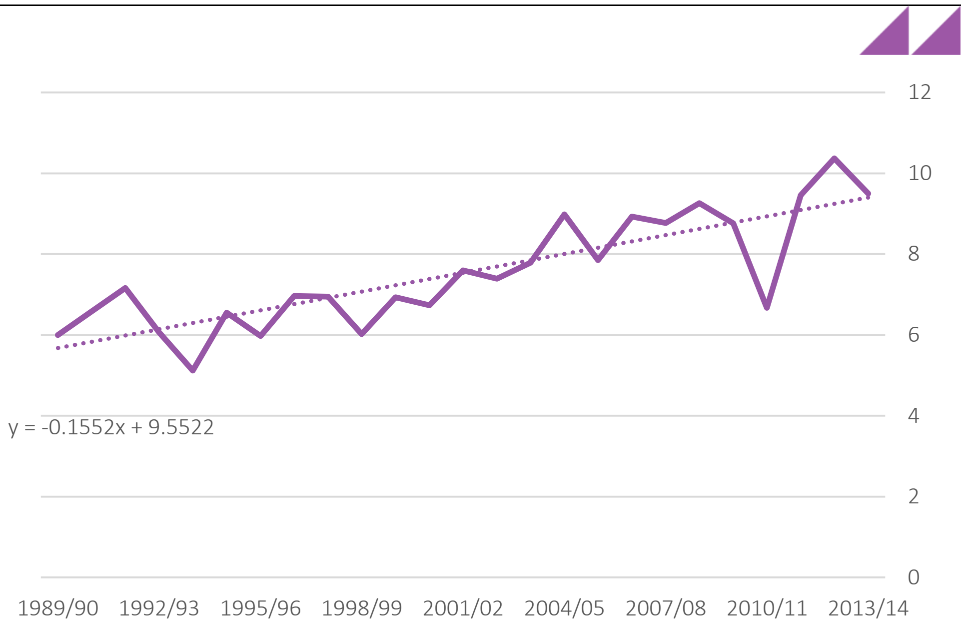
ACIL Allen finds that CSIRO's cotton varieties project has delivered a net benefit of $149.3 million between 2006/07 and 2013/14. This builds upon impressive net benefits delivered between 1973 and 2001 ($5 billion according to a 2002 CIE study), and between 2002 and 2005 ($65 million per annum, according to a 2006 ACIL Tasman study), noting that these two studies based their analysis on reduction in input cotton farming input costs, whereas this analysis focuses only on benefits from yield productivity gains (CIE 2002, ACIL Tasman 2006).

The data underlying this net benefit calculation is laid out in Table C8. The methodology underlying this cost benefit analysis is described below.

#### Calculation of cotton yield baseline and counterfactual

The cotton yield in Australia between 1989/90 and 2013/14 is shown in Figure C6. A linear trend has been fitted to remove the volatility arising from factors such as weather variations between years.

Figure C6 **Australian cotton yield (bales per hectare) - 1989/90 to 2013/14**




Source: Cotton Australia, Australian Cotton Production Statistics

The cotton productivity level in 2006/07 (based on the value of the fitted trend line in 2006/07 rather than the actual value) is the assumed baseline for this cost-benefit analysis.

**To establish a counterfactual, we have made various assumptions**

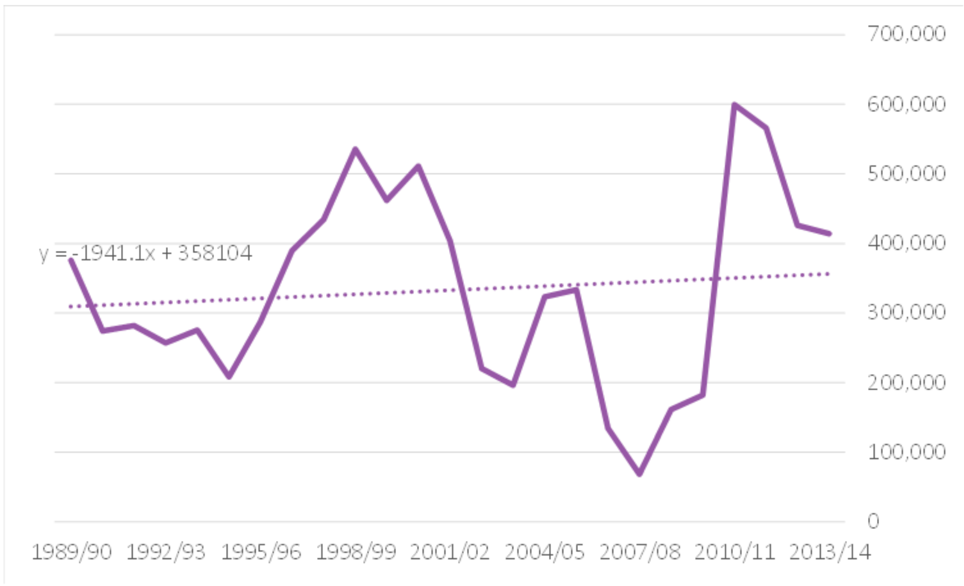
To establish a counterfactual, we assume no further increase in cotton yield productivity post-2006. As stated in the discussion of the counterfactual in Section C.4.2, in the period 2006/7 to 2013/14, average cotton productivity (measured as cotton produced per hectare) increased by approximately 15 per cent. Given that CSIRO cotton varieties accounted for over 90 per cent of cotton seeds sold in Australia by 2005, and 100 per cent of cotton seeds sold in Australia by 2009, it is highly unlikely that such a large increase in productivity would have taken place absent CSIRO. Therefore, to establish a counterfactual scenario against which the additional benefits of CSIRO's cotton varieties can be measured, this analysis freezes yield productivity levels at the baseline (2006/7).

In addition to revenue from increasing cotton production per hectare, this CBA also measures revenue from increased production of 'fuzzy seed' per hectare. Fuzzy seed refers to cotton seeds that are picked up in lint harvesting machines by cotton ginners, which are then processed into cotton seed oil or livestock fodder. CSIRO estimates that the average value of fuzzy seed is equal to roughly 10 per cent of the revenue from the sale of cotton lint (CSIRO, 2014). This means that increased cotton growing productivity leads to increases in revenue from both lint and cotton seed production per hectare.

### Calculation of cotton prices and area under cultivation

To analyse the expected future benefits between 2014/15 and 2024/25, ACIL Allen has assumed that the future cotton price in real terms will remain static at $470 per bale from 2014/15 onwards. This price has been calculated based on our analysis of historical cotton prices from 1997 to 2013. Real production costs are assumed to be constant at $360 per bale in 2014-15 dollars based on the average production cost per bale between 2011 and 2013 as reported by CRDC in its 'Australian Cotton Comparative Analysis 2013 Crop' publication. All historical cotton prices are inflation adjusted to 2014 real prices.

Figure C7 **Total cotton cultivation area in Australia, 1989/90 to 2013/14 (hectares)**




Source: Cotton Australia, Australian Cotton Production Statistics

For the purposes of this analysis, ACIL Allen has frozen the total area of land under cotton cultivation between 2014/15 and 2024/25 at 300,000 ha. The decision to hold total area under cultivation constant for the purposes of our forecast is underpinned by two considerations. First, according to CSIRO researchers, this is the figure most commonly used in the cotton industry itself when forecasting future levels of cotton production. Second, this figure closely corresponds with the historical annual average number of hectares under cotton cultivation between 1989/90 and 2013/14, which sits at 322,870 hectares according to data from Cotton Australia (Cotton Australia, 2014a). While historic data in Figure C7 (above) would suggest a gradual increase in total hectares under cotton production, high levels of year-to-year volatility suggests that resting this cost benefit analysis on an assumption that total hectares under cotton cultivation will continue to expand may risk overstating future benefits. Moreover, expectations of increasingly extreme weather events within a broader trend of increasing dryness in south-east Australia as a result of climate change serves to heighten the dangers of seeking to predict total area under cotton cultivation over the coming decade. Historically high levels year-to-year volatility in total area under cotton cultivation can be expected to continue.

### Attribution level and exclusions

**We have assigned a conservative 60 per cent attribution rate to CSIRO**

We assume that some of the increase in yield productivity is due to breeding of new cotton varieties, some yield productivity increase is due to changing farm management practices, and some yield productivity increase is due to the interaction of the two. Using the findings of Liu *et al* (2013) (which suggested that 48 per cent of the yield productivity gain in Australian cotton farming can be attributed to genetics, 28 per cent to farm management and 24 per cent to genetics-management interaction), we attribute 60 per cent (48% + [24%/2]) of the increased cotton yield productivity since 2006/7 to CSIRO's cotton strains research.

We do not count the benefits of decreased pesticide use and greater water efficiency in this cost-benefit analysis, although these have certainly been valuable benefits that have been delivered over the lifespan of the cotton varieties research project as a whole. Data from Cotton Australia suggests that water efficiency has levelled out at around 2.5 ML per tonne of cotton produced since 2008. This suggests that the largest efficiency gains in water use took place largely prior to our analysis period of 2006/7 to 2013/14.

Similarly, pesticide use is already extremely low, currently sitting at around 0.2g per kg of cotton lint produced (a 95 per cent reduction in pesticides use over the last 15 years) (Cotton Research and Development Corporation, 2014b). With pesticide use at very low levels, the marginal benefits of additional reductions will also be low. This indicates that the greatest gains in pesticide use reduction also took place prior to 2006/7.

### Results

**The internal rate of return on investment over last eight years is almost $150 million**

From 2006/7 to 2013/14, the total value of additional cotton production due to CSIRO's cotton varieties research project is equal to approximately $206.7 million in 2014 dollar terms. Total project input costs of $52.08 million adjusted for inflation are equal to approximately $57.37 million in 2014 dollar terms (see Table C7 – note that the same consumer price index figures applied to input costs also apply to the benefit valuation in Table C8). When total input costs of $57.37 million are factored in, net benefits attributable to CSIRO stand at $149.3 million in 2014 dollar terms, representing an internal rate of return of 93 per cent.

**Future benefits attributable to CSIRO are projected to be over $379 million**

Forecasts to 2024/25, based on expected bales/ha yield gains provided by CSIRO scientists, suggest that CSIRO's cotton varieties research could deliver additional benefits equal to approximately $632.4 million under a 5 per cent discount rate, assuming cotton lint prices, production costs and area under cotton cultivation are held constant. Remembering that this case study attributes 60% of increasing cotton yield to CSIRO's cotton breeding project, this brings net benefits attributable to CSIRO between 2014/15 and 2024/25 to $379.45 million.

Table C7 **CSIRO input costs adjusted for inflation**

| Year | Total actual input cost ($ million) | CPI (Dec) | Total real input cost ($2014 million) |
|---|---|---|---|
| 2006/07 | 4.573 | 86.6 | 5.677 |
| 2007/08 | 4.878 | 89.1 | 5.885 |
| 2008/09 | 5.01 | 92.4 | 5.829 |
| 2009/10 | 5.313 | 94.3 | 6.057 |
| 2010/11 | 5.78 | 96.9 | 6.412 |
| 2011/12 | 6.006 | 99.8 | 6.469 |
| 2012/13 | 6.218 | 102 | 6.553 |
| 2013/14 | 7.051 | 104.8 | 7.233 |
| 2014/15 | 7.252 | 107.5 | 7.252 |
| **Total** | **52.081** | | **57.367** |

Source: ACIL Allen Consulting; CSIRO

Table C8 **CSIRO cotton varieties benefit valuation**

| Year | Area cultivated | Yield | Counterfactual yield | Increase in yield | Price in $2014 | Production cost | Net value of additional production | Additional fuzzy seed revenue | CSIRO-attributed benefit |
|---|---|---|---|---|---|---|---|---|---|
| | **(ha)** | **(bales/ha)** | **(bales/ha)** | **(bales/ha)** | **($2014/bale)** | **($/bale)** | **($)** | **($)** | **($)** |
| 2006/7 | 134,290 | 8.3106 | 8.1554 | 0.1552 | $464 | $338 | 2,631,507 | 263,151 | 1,736,795 |
| 2007/8 | 68,585 | 8.4658 | 8.1554 | 0.3104 | $481 | $382 | 2,103,205 | 210,321 | 1,388,115 |
| 2008/9 | 161,390 | 8.621 | 8.1554 | 0.4656 | $492 | $426 | 4,968,965 | 496,897 | 3,279,517 |
| 2009/10 | 182,000 | 8.7762 | 8.1554 | 0.6208 | $555 | $449 | 11,995,644 | 1,199,564 | 7,917,125 |
| 2010/11 | 599,630 | 8.9314 | 8.1554 | 0.776 | $534 | $388 | 67,757,527 | 6,775,753 | 44,719,968 |
| 2011/12 | 566,000 | 9.0866 | 8.1554 | 0.9312 | $567 | $346 | 116,260,387 | 11,626,039 | 76,731,856 |
| 2012/13 | 425,786 | 9.2418 | 8.1554 | 1.0864 | $512 | $371 | 65,318,157 | 6,531,816 | 43,109,984 |
| 2013/14 | 414,000 | 9.397 | 8.1554 | 1.2416 | $438 | $356 | 42,150,327 | 4,215,033 | 27,819,216 |
| 2014/15F | 300,000 | 9.5522 | 8.1554 | 1.3968 | $470 | $360 | 46,094,400 | 4,609,440 | 30,422,304 |
| 2015/16F | 300,000 | 9.7074 | 8.1554 | 1.552 | $470 | $360 | 51,216,000 | 5,121,600 | 33,802,560 |
| 2016/17F | 300,000 | 9.8626 | 8.1554 | 1.7072 | $470 | $360 | 56,337,600 | 5,633,760 | 37,182,816 |
| 2017/18F | 300,000 | 10.0178 | 8.1554 | 1.8624 | $470 | $360 | 61,459,200 | 6,145,920 | 40,563,072 |
| 2018/19F | 300,000 | 10.173 | 8.1554 | 2.0176 | $470 | $360 | 66,580,800 | 6,658,080 | 43,943,328 |
| 2019/20F | 300,000 | 10.3282 | 8.1554 | 2.1728 | $470 | $360 | 71,702,400 | 7,170,240 | 47,323,584 |
| 2020/21F | 300,000 | 10.4834 | 8.1554 | 2.328 | $470 | $360 | 76,824,000 | 7,682,400 | 50,703,840 |
| 2021/22F | 300,000 | 10.6386 | 8.1554 | 2.4832 | $470 | $360 | 81,945,600 | 8,194,560 | 54,084,096 |
| 2022/23F | 300,000 | 10.7938 | 8.1554 | 2.6384 | $470 | $360 | 87,067,200 | 8,706,720 | 57,464,352 |
| 2023/24F | 300,000 | 10.949 | 8.1554 | 2.7936 | $470 | $360 | 92,188,800 | 9,218,880 | 60,844,608 |
| 2024/25F | 300,000 | 11.1042 | 8.1554 | 2.9488 | $470 | $360 | 97,310,400 | 9,731,040 | 64,224,864 |

*Note:* All forecasts are marked by an ‘F’ next to the year in column one and are highlighted in purple. Figures in purple are forecasts based on analysis of historical data.
Source: ACIL Allen Consulting, CSIRO, Cotton Research and Development Corporation (CDRC) 2014a

### C.5.4 Impact pathway diagram

Table C8 presents CSIRO's impact framework for its work on cotton varieties.

Figure C8 **CSIRO Cotton varieties - impact**

| INPUTS | ACTIVITIES | OUTPUTS | OUTCOMES | IMPACTS |
|---|---|---|---|---|
| ▪ CSIRO investment<br>▪ Cotton Research and Development Corporation funding<br>▪ Cotton Seed Distributors funding | ▪ CSIRO research on the development of new varieties of cotton<br>▪ Establish, monitor and review strategic research targets based on industry benchmarks<br>▪ Extensive regional testing of new variety prototypes on a large scale<br>▪ Importation of new germplasm for evaluation and inclusion in breeding projects<br>▪ Crop management and post-harvest techniques and technologies research | ▪ 102 new cotton varieties released onto the market over the past 30 years: bred to favour disease/pest resistance, high yields, water efficiency, high fibre quality<br>▪ Pland Breeders Rights<br>▪ Publications | ▪ 100 per cent of Australian cotton crops planted with CSIRO varieties; strong overseas sales<br>▪ Increased economic activity through Australia's cotton production value chain<br>▪ Licencing fees<br>▪ New products and services | ▪ Reduced chemical contamination from insecticidal sprays<br>▪ Increased water use efficiency<br>▪ Improved quality of life & health<br>▪ Social licence to operate and community confidence<br>▪ Increased sustainability of rural communities<br>▪ Increased productivity of cotton production<br>▪ Increased international trade<br>▪ Employment, contribution to GDP |

Source: ACIL Allen Consulting

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