Designing a Future for Australian Cotton

CRDC Futures Program

Barnett Consulting

COTTON FUTURES

Australian Government
Cotton Research and Development Corporation

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Acknowledgements

I would like to express sincere gratitude to the many people who participated in the workshops and gave so generously of your time and ideas. Your insights have driven this project and I also hope it has introduced some new folks to cotton and brought everyone ever so slightly closer together on the journey towards a bright and shared future for Australian cotton.

A great debt of thanks is owed to Bruce Finney, Ian Taylor and the CRDC program managers for their contributions and trust in the process. There is great ambition for the Futures Program within the CRDC giving it the best possible chance of success.

Image

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Introduction

Scope

In October 2014 the Cotton Research and Development Corporation (CRDC) engaged Barnett Consulting to undertake a strategic roadmapping exercise. The scope of the project was to better understand the major trends and drivers affecting the cotton industry out to 2029 and translate them into opportunities, challenges and transformative investment options that can be addressed in the short and medium term.

Method

This project report 'Designing a Future for Australian Cotton' is the result of an intensive three-month engagement with experts from within and outside the cotton industry.

The method chosen for this project was 'strategic roadmapping'. Strategic roadmapping is a technique that links and translates long-term vision into short and medium term opportunities in the context of uncertainty and change. By drawing a group of experts together and supporting discourse around customised, thought-provoking tools, the technique can help large groups share language and understandings that are important in working together in the long term.

This method was chosen because complex and uncertain problems require adaptive approaches that help us think broadly and systematically about the 'big picture' and encompass social, economic and environmental interactions. Through developing a shared understanding of how the future system may operate we can place technical details in their proper context. The most important opportunities, barriers and risks then become more apparent and allow participants to act together and realise their preferred future.

CRDC set three themes to form the Futures Program as developed in the CRDC Futures Forum workshop held in December 2013. The themes and their goals are:

- **Profitable Futures**. To increase cotton producer profitability through improved productivity and certainty of production.
- **Sustainable Futures**. To achieve an increasingly resilient and responsible cotton industry.
- **Competitive Futures**. To capture increased value through supply chain transformation and development of new products and markets.

Further detail on the Futures Program and constituent themes can be found in the following section.

As an initial step in the research method (see Figure 1), a desktop scoping study produced one theme briefing paper for each theme outlining relevant trends, issues and background material. The theme briefing papers are included in the appendix. The findings from the scoping study, theme briefing papers and consultation with CRDC identified key disciplines that would be important to engage in the theme-based expert panel roadmapping workshops:

- **Profitable Futures**: agricultural economics, autonomous systems, information engineering, data analytics, plant breeding.

- **Sustainable Futures**: understanding the textile customer, electronics (flexible, batteries, composites), fabric blends with synthetic and natural fibres / cellulose, logistics / operations research, design.

- **Competitive Futures:** social science, complex systems, land use trade-offs, climate/plant physiology, operations research, data and analytics standards, marketing.

Participant lists were then generated in collaboration with the CRDC to provide expertise from within and outside the cotton industry. Participant lists for each of the workshops are included in the appendix.

The panels were presented with the theme briefing papers as a starting point to explore the major trends around the cotton industry and to identify what *their* priorities would be for future oriented research investment.

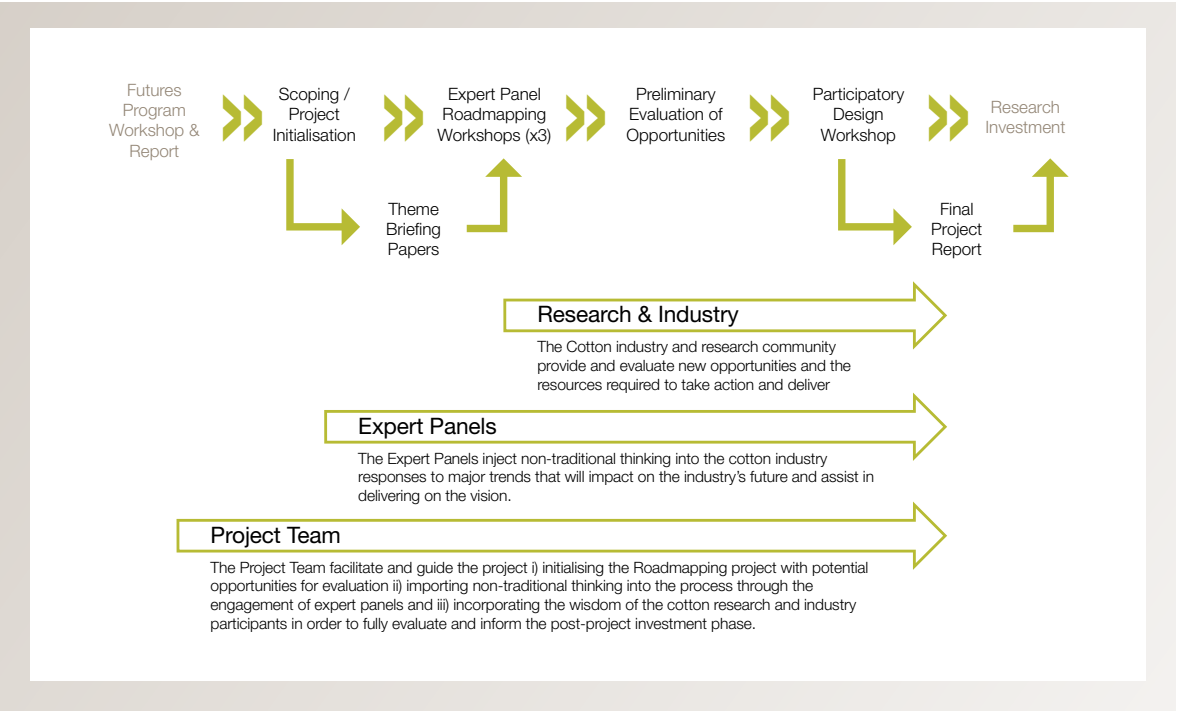


Figure 1 Project engagement workflow

The method applied in the workshops followed an adapted Strategic Roadmapping technique, which included the following four elements:

- Agreement on vision.
- Mapping of the key future trends and issues.
- Understanding the current industry capability, institutions and technology.
- Mapping opportunities, their impacts, required partners and priorities.

Lastly, a fourth workshop was hosted, with key industry participants from across the cotton supply chain, which included:

- Investigation of the trends, opportunities and assumptions arising from the theme-based workshops.
- Analysis to determine what other opportunities would be important in addition to current industry activities and what had been proposed in the theme-based workshops.
- Ranking of opportunities by feasibility and scale of impacts.
- Planning the opportunities as major projects and scale of potential investments.

Further interviews sourced on an ad-hoc basis contributed to the preparation of this report.

Vision and Strategy

Industry Strategy

Australian cotton industry strategy for research and development is coordinated by the Cotton Innovation Network[1]. Participants in this network are CRDC, Cotton Australia, Cotton Seed Distributors, CSIRO, the Australian Government's Department of Agriculture, the Queensland Government's Department of Agriculture, Fisheries, Forestry, the NSW Department of Primary Industries and universities, through the Australian Council of the Deans of Agriculture.

The Cotton Innovation Network identifies five priority areas for research, development and extension:

- Plant varieties.
- Farming systems.
- People and communities.
- Products and markets.
- Development and delivery.

According to the network, these five areas are interrelated as shown in the following diagram.

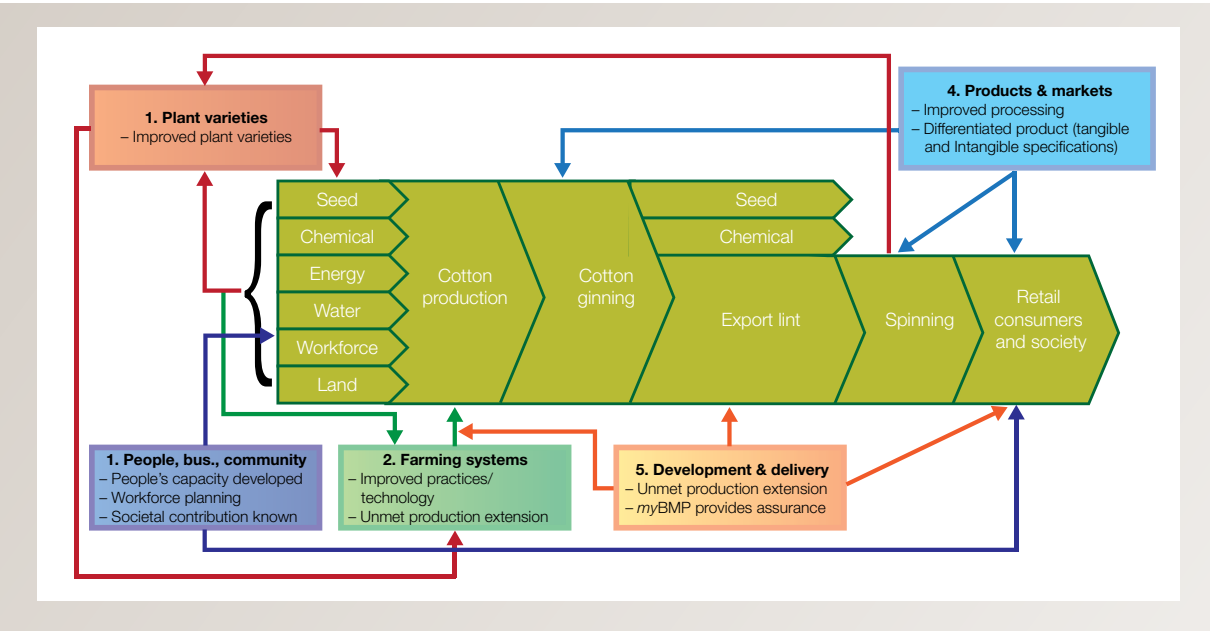


Figure 2 Cotton Innovation Network priority areas[2]

[1] Cotton Innovation Network details http://www.crdc.com.au/cotton-innovation-network-0
[2] CRDC. 2013. Strategic R&D Plan 2013-18

The major focus for the Cotton Innovation Network is to harmonise research efforts to gain efficiencies in the priority areas through monitoring implementation of the strategy, improving collaboration and removing duplication.

CRDC Strategy

The CRDC strategy prioritises three core research programs including:

- **Farmers**: cotton is profitable and consistently the farmer's crop of choice.
- **Industry**: the Australian cotton industry is the global leader in sustainable agriculture.
- **Customers**: the Australian cotton industry captures the full value of its products.

People and **Performance** are two underpinning and integrated research programs to complement delivery and capability for the industry. The elements of the core and underpinning programs of the strategy are illustrated in the diagram below.

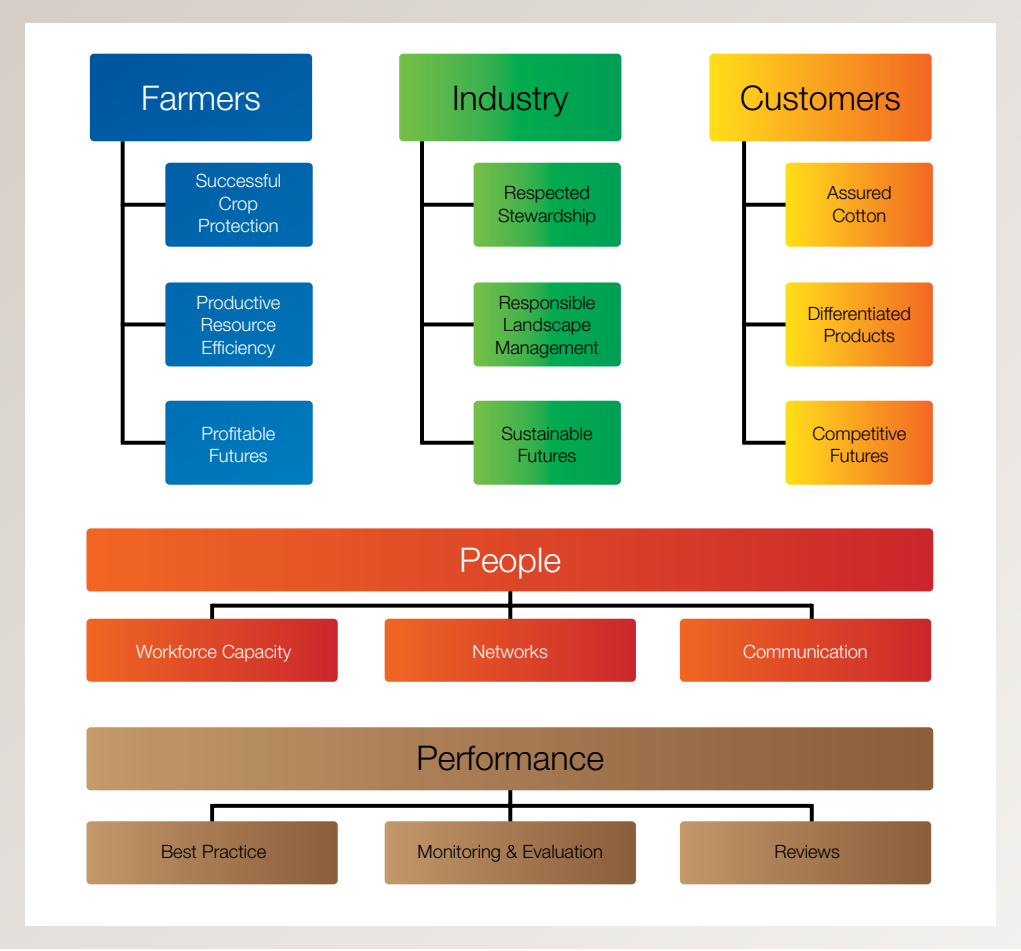


Figure 3 CRDC Strategy research programs [2]

[2] CRDC. 2013. Strategic R&D Plan 2013-18

CRDC Futures Program

The CRDC Futures Program sets ambitious goals for a portfolio of research investment focused on long-term innovations that will transform the industry to ensure it is profitable, sustainable and competitive in 20 years time.

In December 2013 a workshop with government, industry and research participants was hosted by CRDC to develop a series of goals and targets for the CRDC Futures Program. The goals and targets were then translated into the three themes mentioned earlier (and illustrated below) and analysed in workshops held in September and October 2014.

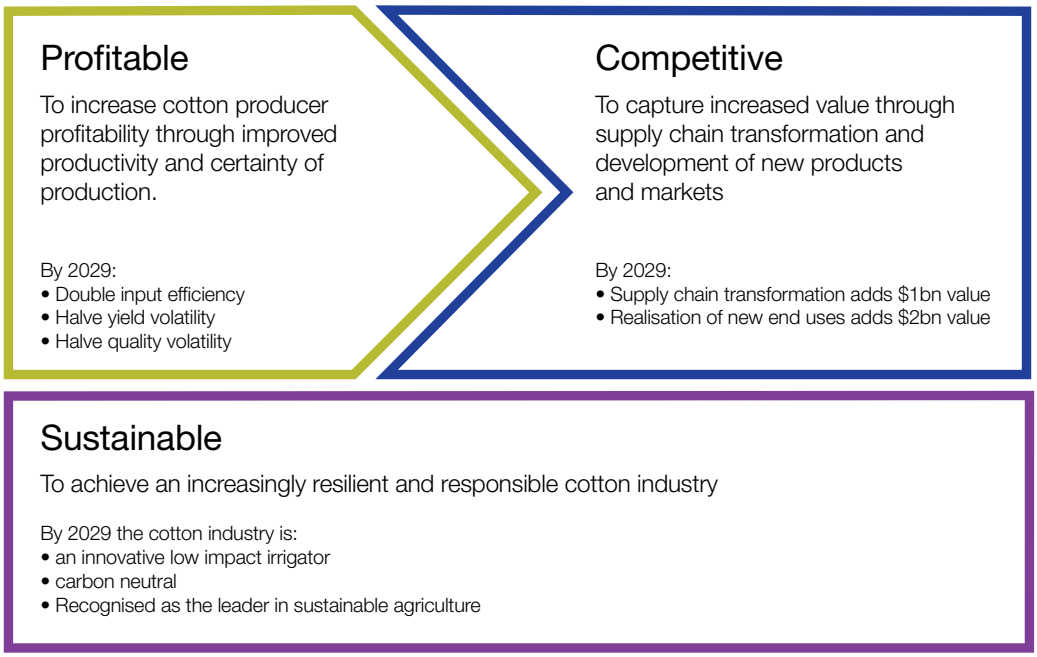


Figure 4 CRDC Futures Program Themes, Goals and Targets

The Profitable Futures Theme is focused on the cotton production system and is linked with Competitive Futures Theme through the common objective of smoothing cotton production volumes at an industry scale. At a high level this is thought to contribute to Competitive Futures through trusted supply that regular customers of Australian cotton can depend on. See Figure 5 for an illustration of how the emergent properties of each theme overlap with the other Futures Program themes and with the CRDC Strategic priorities.

The Competitive Futures Theme looks at the supply chain by considering the interactions from the production system through to the end user and disposal or recycling. A priority for this theme is to drive value for growers. This may translate as informing changes in the production system to maintain access and premiums or linking changes in the supply chain with changes in the production system that drive competitiveness for the Australian cotton industry.

The Sustainable Futures Theme is considered as an underpinning theme for the Futures Program. The other themes cannot be considered successful without success for Sustainable Futures. Additionally, this theme supports Profitable Futures objectives because improvements in efficiency of input use have also led to a reduction in the impacts of inputs on the environment and society. This theme supports Competitive Futures as efficiencies in the supply chain and reductions in environmental and societal impacts are believed to assist in marketing and overall competitiveness. Some of these dynamics and the relationship with the core CRDC outcomes are shown in the diagram below.

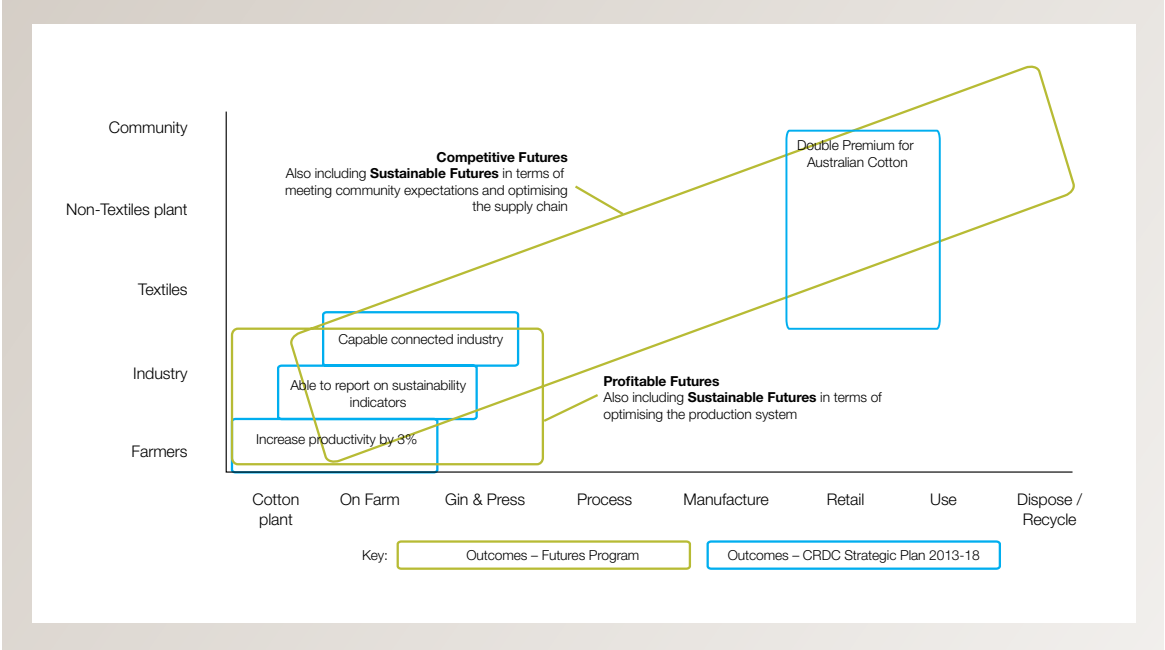


Figure 5 CRDC Strategic Plan Outcomes and Futures Themes

Profitable Futures

This section summarises the trends and drivers identified in the Profitable Futures theme workshop and related material arising from the participatory design workshop. Subsequently, key opportunities that were developed by participants are summarised.

Trends and Drivers

The expert panels were asked to think about future trends out to 2029 that may affect the objectives of the relevant theme. Key trends identified by the expert panel participating in the Profitable Futures workshop are outlined in the diagram below.

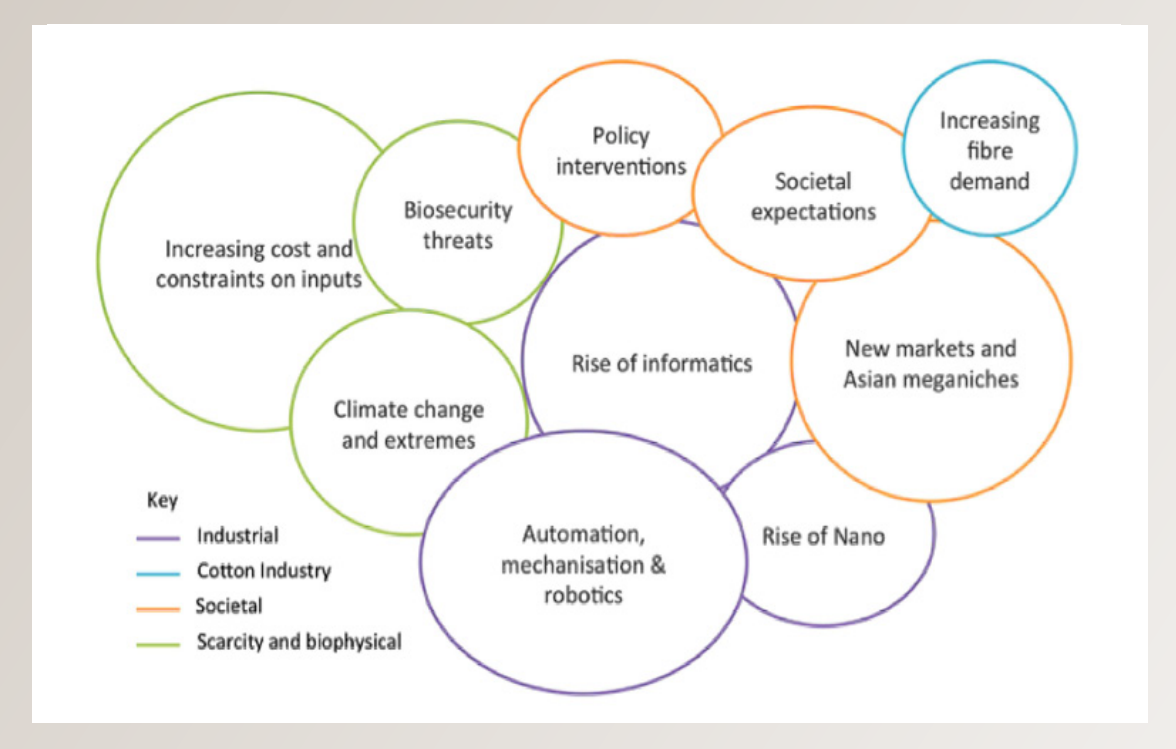


Figure 6 Visualisation of the key trends and drivers related to Profitable Futures

- **Increasing cost and constraints on inputs** (i.e. land, water, labour, energy, fertilisers and chemicals), **biosecurity threats** and **climate change and extremes**. These trends largely represent a set of constraints experienced by the cotton industry as part of a classic 'cost-price squeeze' where increasing costs and risks of production appear to be associated not only with market conditions but also with increasing challenges to the biophysical constraints of production. The biophysical constraints and risks above are amplified by ongoing changes to the climate and extremes of weather.

- The expert panel pointed to an increase in the availability and relevance of new technologies, in particular **informatics, automation, mechanisation, robotics and nanotechnologies.** These were raised as important trends that agriculture can make greater use of in the future.

- Three trends are grouped together - increasing **policy intervention**, **societal expectations** and the **emergence of new markets**. The policy intervention trend is indicating increasing use of policy by government to achieve economic, environmental and societal outcomes. The societal expectations trend refers to changes in the way society relates to agriculture and indicates a greater interest in the origin of cotton as well as social and environmental circumstances under which cotton is produced. The new markets trend refers to the possibility of markets other than the traditional textiles markets becoming important for cotton. Some examples here include soft-tech, rapid customisation, electronics and health. **Asian mega-niches** refers to the approximately 3.2bn middle class Asians that will contribute to increased demand for many commodities by 2020, swelling to 4.9bn by 2030[4]. Niche products or services delivering to this demographic have the potential to be significant.

- **Increasing fibre demand.** The expert panel recognised that increasing fibre demand is an important trend when the proportion of global fibre demand attributed to cotton is shrinking. An additional thought related to this trend is the expected emergence of the 'cellulose gap'. The cellulose gap refers to excess demand for 'natural' fibres that cannot be met by predicted cotton production.

Box 1. Impact of transformational business models

A background issue that arose from discussions relating to natural resource constraints was the transformation of business models from product centred to service centred ("servitisation of products)". Examples of such transformations can be found in IBM, GE, Apple and many others. These transformations emerged first in technology companies and are now being seen in agriculture.

An example of this servitisation, and the importance of informatics and data science to the future of agriculture, is Monsanto's recent purchase of the Climate Corporation (an agriculture services company focused on insurance) for nearly US$1bn and offerings such as FieldScript. These changes will help Monsanto sell more products and attract customers into a services ecosystem (operating as a 'sticky garden' where it's attractive to stay in part due to the difficulties in leaving for another services ecosystem).

Another feature of some of the most successful companies is the adoption of assymetric business models. An asymmetric business model crosses industries and migrates profits from one market to another. There are several examples, and in each case a company drives profits to their core business by competing in an adjacent and complementary market. An unfair advantage is often created by bundling core products and services with new demand and demonetising the target market where incumbents are left scrambling without a chance to compete. Apple, Google and Amazon are among the most successful examples.

[4] ESPAS. 2011. Global trends 2030 – Citizens in an interconnected and polycentric world.

Opportunities

The following opportunities were identified and characterised by participants in workshops and forums associated with this project.

Agri-intelligence Systems (1.1)

Expert panel: Impact ~$300m p.a., 10 years away. Key risks include capability availability, trust in confidentiality of data and underestimating cost.

Agri-intelligence Systems is complementary with the Autonomous Farming opportunity listed immediately below. Agri-intelligence Systems targets the increasing complexity of farming enterprise operations arising from both increasing volumes of data and looking to optimise operations more tightly, and at finer scales, than ever before. Agri-intelligence Systems that combine information infrastructure, risk analytics and modelling in an interoperable way help deal with different scales of variability in the production system in space and time, reduction and optimisation across all inputs including labour, energy, water and chemicals and improved decision-making under uncertainty. The panel suggested that it would be important for cotton industry to collectively own, share and use information with an initial focus on integrating and leveraging existing data sets to benefit growers, which are limited by their fragmentation (e.g. Boyce comparative, myBMP, sustainability report, farm data).

Autonomous Farming (1.2)

Expert panel: Impact ~$350m p.a., 10 years away. Key risks include network coverage, energy, system integration, new regulations and short-term investment horizon for farming enterprises.

As noted Agri-intelligence Systems and Autonomous Farming are complementary opportunities. Robots (ground and air) in agriculture will play a key role as enabling factors for tighter control and optimisation of production. Robots can be part of the sensing network, but also act on the crop. An information infrastructure allows analysis of big data, novel management practices and autonomous systems for decision-making. This combination of technologies can then be deployed to minimise the use of inputs (energy, labour, chemicals) and at the same time increase productivity and reduce volatility in both yield and quality. Some elements required for Autonomous Farming are already available including sensors, networks, GIS, GPS, robots, UAVs with an initial focus on adaptation and integration. Further development is required across agriculture to develop Autonomous Farming capability.

Capability to Adopt New Technology (1.3)

Arose from both Profitable Futures workshop and participatory design workshop. No consensus on impact and timing but possible 2-5 times speed of adoption. Key risk resistance to change or gaining traction, failing to determine the right limiting skills or trigger for undesirable structural change in industry.

This opportunity reflects an identified need to develop capability within the cotton farming industry such that adoption of new technology is possible. It also reflects required changes in the way technology is developed such that mainstream growers (i.e. not just the innovators) are able

to adopt technology that assists them deal with the 'data deluge', for example, instead of adding to it. Rather than replacing the grower in the decision making process, this opportunity is about the integration of knowledge into decision support that focuses on adding value and certainty to the grower's decision-making process.

Future Cotton Farm (1.4)

Arose from participatory design workshop. Combined impact and risks of Agri-intelligence Systems & Autonomous Farming opportunities.

This opportunity combines the Autonomous Farming and Agri-intelligence Systems opportunities above integrating the best of future developments in sensing, robotics and informatics in a future cotton farm. Participants encouraged each other to imagine this opportunity as a 'bare dirt' starting point where the production system would be re-engineered without the constraints of deeply ingrained legacy concepts that inhibit adaptability. For example, a required ratio of one human per tractor may no longer hold true.

Genetics Approaches (1.5)

Arose from participatory design workshop. No consensus on impact and timing. The extent to which this is already being funded and pursued is unclear.

Develop a smart cotton plant that can adapt (or be triggered to adapt) to external stressors while optimising yield and quality. Fully integrated GxExM (Genetics by Environment by Management) approach to take advantage of sensing and analytics technologies.

Summary

The objective of this work was to identify opportunities not currently core of the cotton industry. The diagram shows how the opportunities above map together to deliver on the Profitable Futures theme goal. The rationale for having a focus on the Agri-intelligence Systems and Autonomous Farming is that these efforts must deliver in order to power the Future Cotton Farm. Additionally, the ongoing and critically underpinning investment in capability development and genetics improvements made by a range of actors in the cotton industry is core to adoption of these technologies.

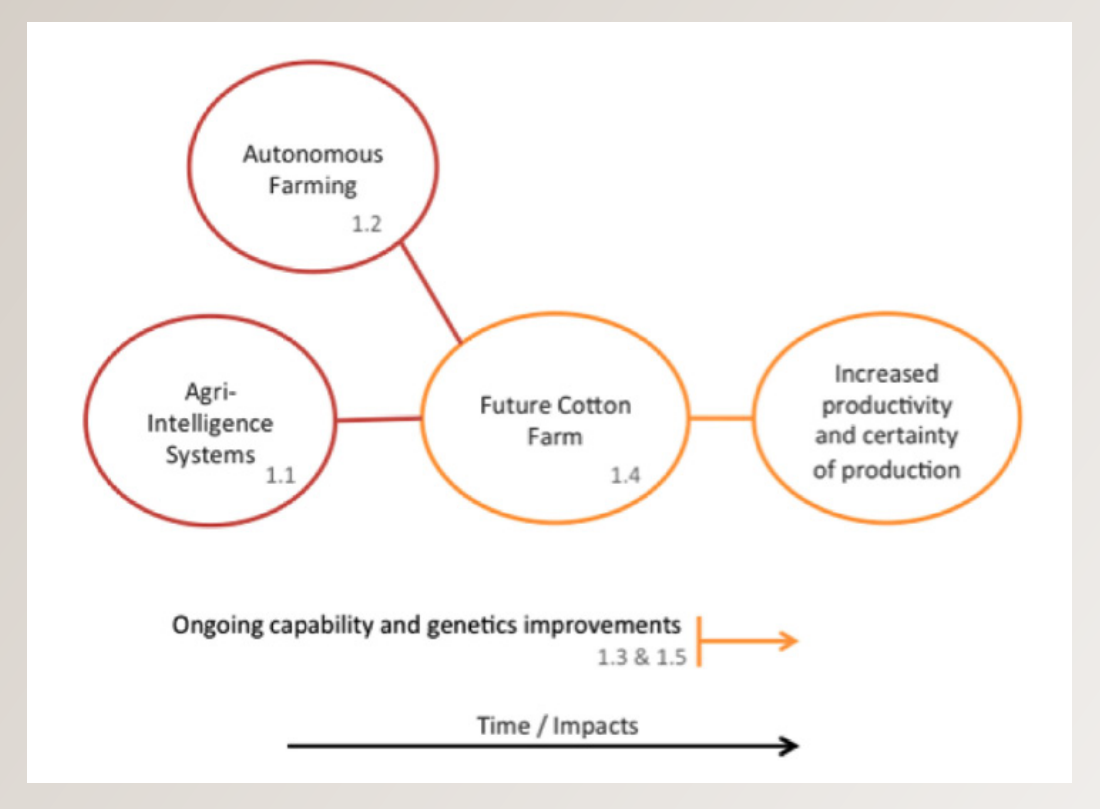


Figure 7 Mapping new opportunities into the Profitable Futures theme

Sustainable Futures

This section summarises the trends and drivers identified in the Sustainable Futures theme workshop and related material arising from the participatory design workshop. Subsequently, key opportunities that were developed by participants are summarised.

Trends and Drivers

Key trends identified by the expert panel participating in the Sustainable Futures workshop are outlined in the diagram below.

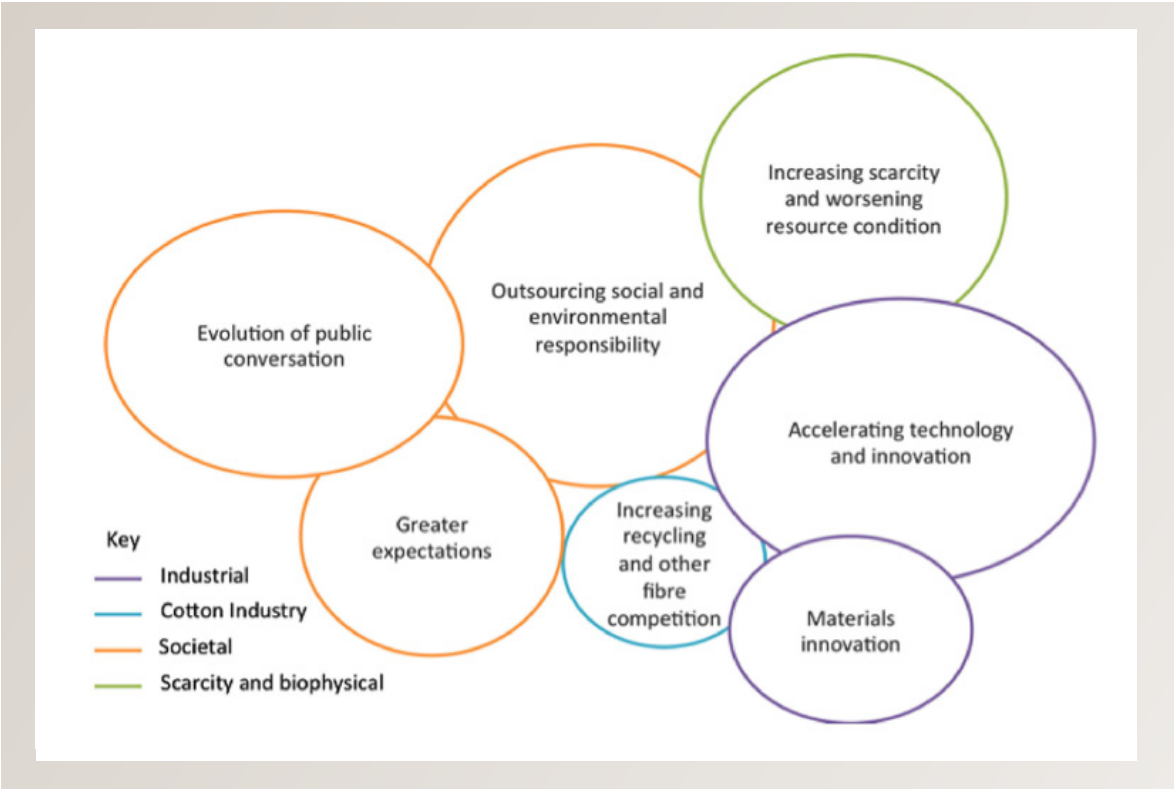


Figure 8 Visualisation of the key trends and drivers related to Sustainable Futures

In congruence with the Profitable Futures expert panel, the Sustainable Futures panel identified society's changing relationship with sustainability.

- **Evolution of public conversation.** While this trend took a focus on changing expectations, demographics and policy reactions in the Profitable Futures theme, the Sustainable Futures panel also focused on the rapidly changing nature of the public conversation. Of particular note was the recognition that individuals may have greater expectations of companies' **environmental and social performance** and delegate their responsibility to understand and manage their impacts back to those same companies.

This was seen to increase a brand's activity in relation to sustainability and ethical production practices.

- **Greater expectations** refers to customers looking for more functional clothing such as for sports or outdoor activities, hygiene or the like.

- The trend titled **increasing recycling and fibre competition** relates to the increase in demand for fibre as a result of population growth coupled with an increase in demand for recycling of fibres after their use. It was noted that brands might increasingly be choosing fibres based on their life cycle analysis and capacity to recycle.

- **Accelerating technologies and innovation.** The Sustainable Futures theme expert panel also indicated that the rise of new technologies and innovation including the area of **materials innovation** was going to have a large impact on the future of cotton. As was seen in the Profitable Futures theme trends, the role of informatics, analytics, robotics and automation was also in people's minds in addition to additive manufacturing, man-made fibres, and our capability to transform materials and blend them for specific purposes. The future possibility of being able to extract greater value from traditional areas of agricultural research through application of these newer disciplines and technologies was also an important aspect of how these trends may impact on the cotton industry.

- The **increasing scarcity** of inputs to agriculture (including phosphorous and potassium) and the **worsening condition of the natural resource base (**e.g. groundwater and land) was indicated as a significant and ongoing challenge for agriculture more generally. Referred to in this discussion was also competition for natural resources such as land and water and the food vs fibre debate.

Opportunities

The following opportunities were identified and characterised by participants in workshops and forums associated with this project.

Atmospheric Water Resources / Non Extracted Water Resources (2.1)

Expert panel: Impact ~$1bn p.a., social license retained, 30 years away. Key risk is cost effective scaling of technology to meet needs of farming enterprise.

This opportunity stems from a desire to access new water resources and use them more efficiently. Water resources could be pulled from the atmosphere and used for irrigation. The attractiveness of this option is to address pressures on the cotton production system to use less conflicted water resources. Participants indicated the solution to water resources issues would still be a mix of new sources and efficiency measures relating to the cotton plant, management and technology.

Carbon Neutral Farming (2.2)

Arose from participatory design workshop. No consensus on impact and timing. Based on $10-20 price on a tonne of carbon the raw value is $7-14m per year plus social license maintained. Energy savings may be more significant.

The carbon neutral farming opportunity as raised at the Participatory Design workshop is more of a goal or perhaps a series of opportunities rather than a particular opportunity. It includes thinking around energy recapture from the production system, low peak energy systems to be compatible with solar or other low carbon intensive energy sources. The participants indicated further investigation is required here.

Plant-Scale Management (2.3)

Expert panel: Impact ~$400m p.a., social license retained, 5-10 years away. Key risk is maintaining synergy with existing cotton research investment and other opportunities focused on same goal.

This opportunity could equally reside in the Profitable Futures theme. It refers to reduction in resource use and closing the gap between potential and realised yield through fine scale resource and crop information and precision management practices. This is made possible through significant leaps in remote sensing, proximal sensing and informatics that translate measurements into information in management timescales. This opportunity links with the Agri-intelligence Systems and Autonomous Farming opportunities.

Traceability (2.4)

Expert panel: Impact ~$200m p.a., social license retained, 2-10 years away (2yrs local with available tech vs 10yrs global). Key risk is socio-technical barriers to adoption.

Traceability was raised as an important opportunity in both the Sustainable Futures theme and the Competitive Futures theme and will be dealt with as a single opportunity here in this section. However, the two angles that were reflected in the different themes included what could be done between businesses to optimise the supply chain and what could be done to manage and communicate sustainability information. The technology to achieve both of these objectives through traceability is believed to exist and the challenge remains in efforts to overcome the socio-technical issues of adoption and high participation rates right through the value chain. Future technologies such as use of biomarkers or traceability embedded in the physical product (carried in a dye, for example) may be useful in determining the source and processing of mixed origins of blends.

Summary

The key aspects of sustainability opportunities as identified by the recent Cotton Futures workshops are also fundamental to delivering on the goals of Profitable Futures and Competitive Futures. Sustainable Futures is an underpinning and supporting theme whose goals must be achieved in order to have truly and satisfactorily met the goals of the other two futures themes.

Again, it must be considered here that the opportunities identify both disciplines and opportunities not currently core to the cotton industry. To be economic, plant scale management may need to be supported by opportunities listed in other themes such as Agri-intelligence Systems and Autonomous Farming. Carbon neutral farming and innovative low impact cotton irrigation will not be delivered by plant scale management alone, but will require other opportunities and core research program investments in a coordinated way.

The traceability opportunity is both related to optimising the supply chain as well as supporting increased consumer and business demand for information about environmental and social circumstances of production.

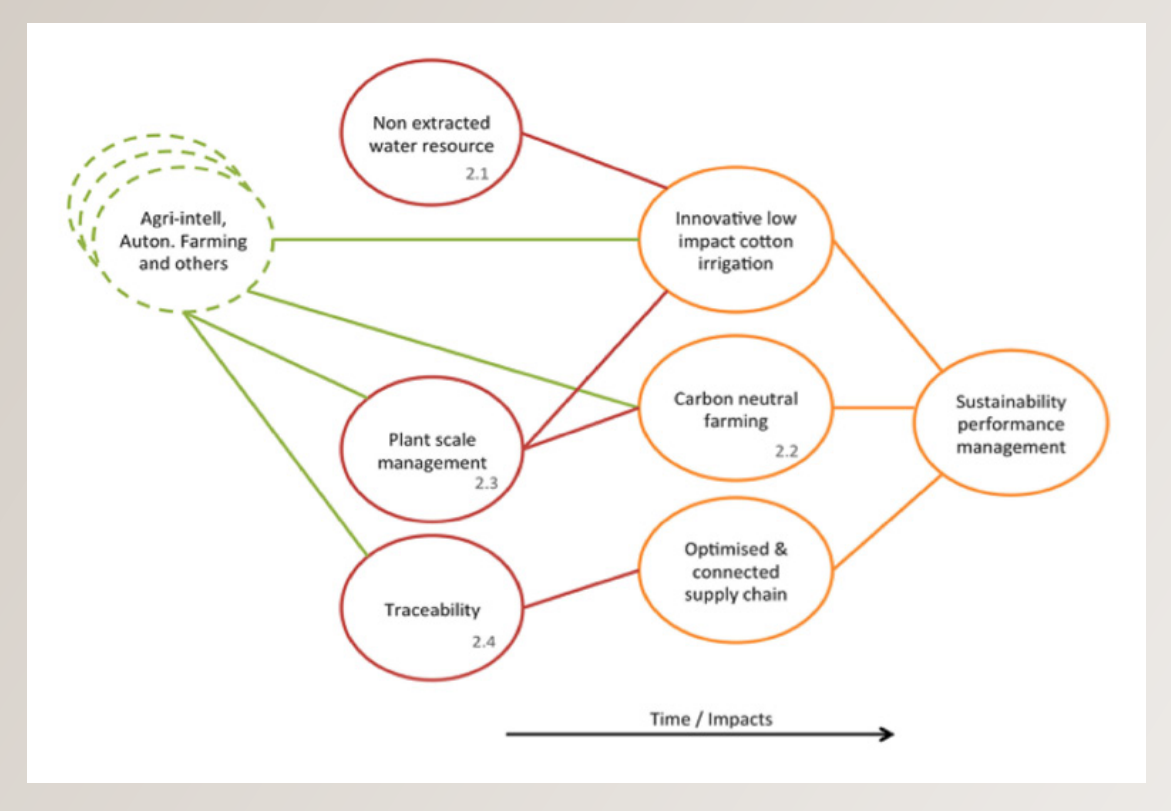


Figure 9 Mapping new opportunities into the Sustainable Futures theme

Competitive Futures

This section summarises the trends and drivers identified in the Competitive Futures theme workshop and related material arising from the participatory design workshop. Subsequently, key opportunities that were developed by participants are summarised.

Trends and Drivers

Key trends identified by the expert panel participating in the Competitive Futures workshop are outlined in the diagram below.

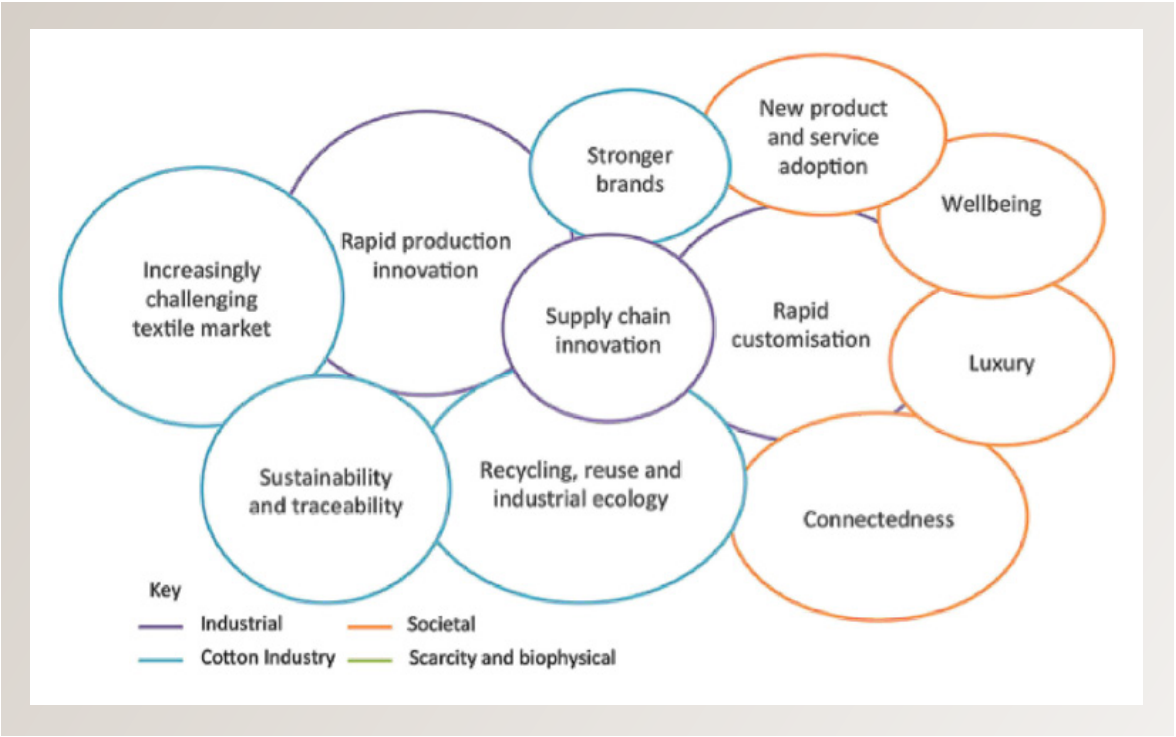


Figure 10 Visualisation of the key trends and drivers related to Competitive Futures

- The **increasingly challenging textile market** is not expected to ease off downward pressure on cotton's market share of global fibre demand. Cotton will continue to compete with a broadening range of man-made fibres while the terms of trade for Australian cotton growers will not dramatically improve. Government intervention in the supply chain and markets including subsidised competition are also factors.

- **Sustainability and traceability** were identified as being deeply linked into the future by the panel. This amounted to achieving competitiveness through better information for consumers and for the supply chain and production system to act upon. In other words, you can't manage what you don't measure. An increasing interest in sustainability and

efficiency by consumers will both be better served by measures that improve connectivity and information flow in the production system and supply chain.

- The trend titled **rapid production innovation** highlights the rate at which production processes are being redesigned and reimagined. In particular, the panel noted novel processing techniques, dye chemistries, sustainable processing solvents and tuning the production system to deliver a product that is interlocked with the processing steps and final product.

- As seen in the other themes there is an increasing trend towards **recycling, reuse** and thinking of the economy as an **industrial ecosystem** where the outputs of one industry are the inputs for another such that limited virgin material is required.

- The panel indicated **supply chain innovation** as a significant factor in the future competitiveness of Australian cotton. Some factors raised were increasing connectivity in the supply chain, reverse logistics, migration of production to low-cost economies and new business models creating new markets.

- **Stronger brands** was a trend that pointed towards more brand ownership taking control of conversations and talking more about origin and the consumer experience.

- **Rapid customisation** refers to the growth in additive manufacturing or 3D printing technologies and how this might affect the textiles or cotton industries. Considerations included trends in design and fabrication happening 'at home' and the possibility of using various cotton products as substrates meeting soft-tech trends.

- The Competitive Futures theme expert panel elucidated more detail around the societal trends by including **connectedness**, **luxury** and **wellbeing** as well as commenting on the increasing speed with which **new products and services will be adopted**.

Understanding the importance of what it will take to adapt the cotton industry to a different future will be critical to achieving a more competitive cotton future. Cotton has been identified in the past as a slow moving industry, but it may be possible to get closer to the end user and participate in the conversation about what consumers want, particularly if the supply chains and manufacturing processes look very different from those that already exist.

Opportunities

The following opportunities were identified and characterised by participants in workshops and forums associated with this project.

Cotton Based Carbon Fibre Yarn (3.1)

Expert panel: Impact ~$200 p.a., 5 years away. Key risk is being able to access a premium for the extra value created.

Compared to alternatives, creating carbon fibre is energy intensive and therefore a high value product. Investigating the potential for cotton to be an input to a process that derives high value carbon fibre was identified as leading to supply chain disruption and accessing new markets for cotton fibre.

Cotton Gin Trash Uses (3.2)

Arose from participatory design workshop. No consensus on impact and timing. Not expected to be significant to cotton growers by expert panel or participatory design workshop.

This opportunity didn't receive full treatment in the participatory design workshop, as it didn't score highly in terms of assessment of the scale of impacts that would result. It essentially encapsulates a drive to connect processing outputs to high value uses and thereby diversifying the cotton production system. The reverse was also raised by participants - thinking about waste streams from other industries that could be utilised in the cotton production system.

Cotton Seed Modification (3.3)

Expert panel: Impact ~$200m p.a., social license contribution, up to 15 years away. Key risk is market acceptance of genetically modified product.

Cotton seed modification refers to the removal of gossypol to improve the characteristics of cotton seed and cotton seed oil for human consumption. Other modifications may lead to livestock feed to improve conversion and therefore livestock productivity. This processing may need to occur post harvest or in a system with genetics approaches.

Dissolving Cotton (3.4)

Expert panel: Impact ~$1bn p.a., disruptive to value chain, 5-8 years away. Key risks are cost effectiveness of solvent/media and favourable characteristics of reconstituted cellulose product.

Dissolving cotton represents a potentially significant departure from the current value chain. Opportunities that arise from affordable and sustainable cotton dissolution are:

- Chemical ginning, potentially on-farm.
- Pure cellulose as an input to manufacturing.
- Complete one-step removal of cellulose from seed.
- Potential reduction in the length of the supply chain.
- Potential use in recycling cotton. A breakthrough in this area would change the objective of cotton farming from quality *and* yield to yield alone.

Novel Treatments for Cotton (3.5)

Expert panel: Impact ~$100m p.a., 5-8 years away. Key risk is that the high cost of dyes may offset energy savings.

Novel treatments for cotton are related to reducing energy demand in the dyeing process, adding functionality to dyes (e.g. thermochromics, traceability, stain blocking, waterproofing, antibacterial, UV stability). These enhancements would assist in competing with rapid market adaptations occurring in the man-made fibre market. In line with CRDC objectives any investment in this opportunity must be fully cognisant of the return on investment to growers and Australia.

Rapid Customisation (3.6)

Expert panel: Impact ~$10m p.a. with more significant long-term value, disruptive to value chain, 5 years away. Key risk is greater suitability of synthetic feedstocks or low fidelity and functionality of 'printed cotton'.

Rapid customisation as an opportunity means to develop a cotton additive print machine. This may incorporate overcoming barriers to the use of cotton in additive manufacturing. This opportunity arises from the increasing demand for customised products delivered on a mass scale and could fit well with 'design at home' and 'print at home' trends where the final products are textile replacements or the emerging soft-tech market. The inputs to an additive print machine could also be any part of the cotton plant.

Supply Chain Diversification (3.7)

Expert panel: Impact ~$120-200m p.a., 5-15 years away. Key risks include the market for recycled fibres and parallel development of cotton dissolution process or other that competes with mechanical separation.

Supply chain diversification is identified to help the cotton industry expand to fill the cellulose gap and potentially entrain extra demand for virgin cotton. This opportunity seeks to grow the use and application of cotton through recycling and incorporation of other cellulose fibres with lint (or lint derivative substrate). The technologies required would be extracting poly from cotton as well as extracting dyes and other treatments.

Supply Chain Optimisation (3.8)

Expert panel: Impact ~$50m p.a., 1-5 years away. Key risks include low merchant participation and ability to capitalise.

Supply chain optimisation is a near term opportunity to improve efficiency in the current supply chain of the Australian cotton industry. This would include optimisation of the supply chain from on-farm to port. The opportunity is not transformative but increases efficiency of the Australian cotton industry and seeks to gain more than 5% reduction in costs within 3 years.

Traceable Cotton (3.9)

This is a repeat of 2.4 as traceability was considered important in two of the three themes.

Summary

At the centre of the Competitive Futures theme is supply chain diversification. On one hand this is represented by adding extra value to the existing supply chain such as with the development of novel dyes that reduce lifecycle energy use. On the other hand is the creation of new value that is either separate or disruptive to the existing supply chain. An example here might be in meeting demand for rapid customisation through 3D printing with cotton.

Translating these opportunities into reality could secure market access and create new demand for cotton but, as raised during the sessions, some careful planning is required to ensure that this new value is linked to increased competitiveness of Australian cotton growers.

As illustrated in the diagram below the workshop participants developed a series of opportunities that cluster around unique yarns (additional value to existing supply chain) and new product classes (new products and markets).

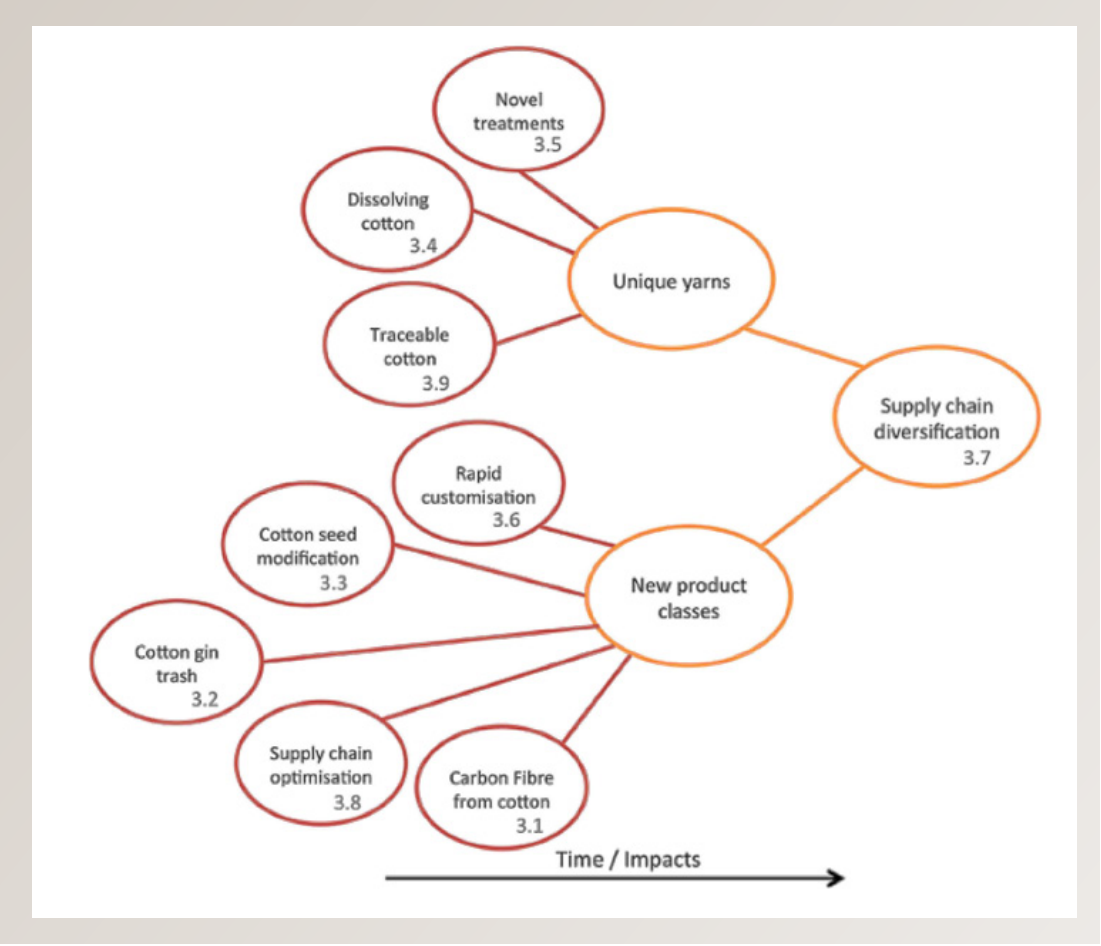


Figure 11 Mapping new opportunities into the Competitive Futures theme

Reflections on Prioritisation

In the fourth and final workshop a roadmapping technique was applied to arrive at a consensus view of the future trends that may affect the Australian cotton industry. Once consensus was reached, participants were asked to evaluate what opportunities the cotton industry should seize or generate to achieve its goals and vision for the future.

As the work was conducted in two stages (expert panels and then cotton industry leadership), it revealed an interesting pattern in the preferences and perceptions about which opportunities were going to be the most successful (high feasibility and high impacts).

The first stage of identification and assessment of opportunities was conducted by an expert panel with only basic knowledge of the cotton industry. The second stage involved cotton industry experts from research and industry across the value chain. Some differences in the assessments of opportunities highlight the potential for a wider industry engagement to promote discourse and familiarity between non-biophysical disciplines and the industry along side the more traditional disciplines that cotton industry calls upon. This journey is already underway through the Cotton Innovation Network and associated efforts and this project has demonstrated a contribution to this new discourse. However, more can be done.

The diagram below highlights this issue by depicting the cotton industry assessment of feasibility and impacts from opportunities raised during this project. Solid line circles indicate an expert panel raised the opportunity as both feasible and likely to result in significant impacts. The dotted-line circles are opportunities that were raised as additional to the expert panel selection and what is already being undertaken in the industry in order to achieve the respective theme goals. The position of each opportunity on the figure was determined during the Participatory Design workshop.

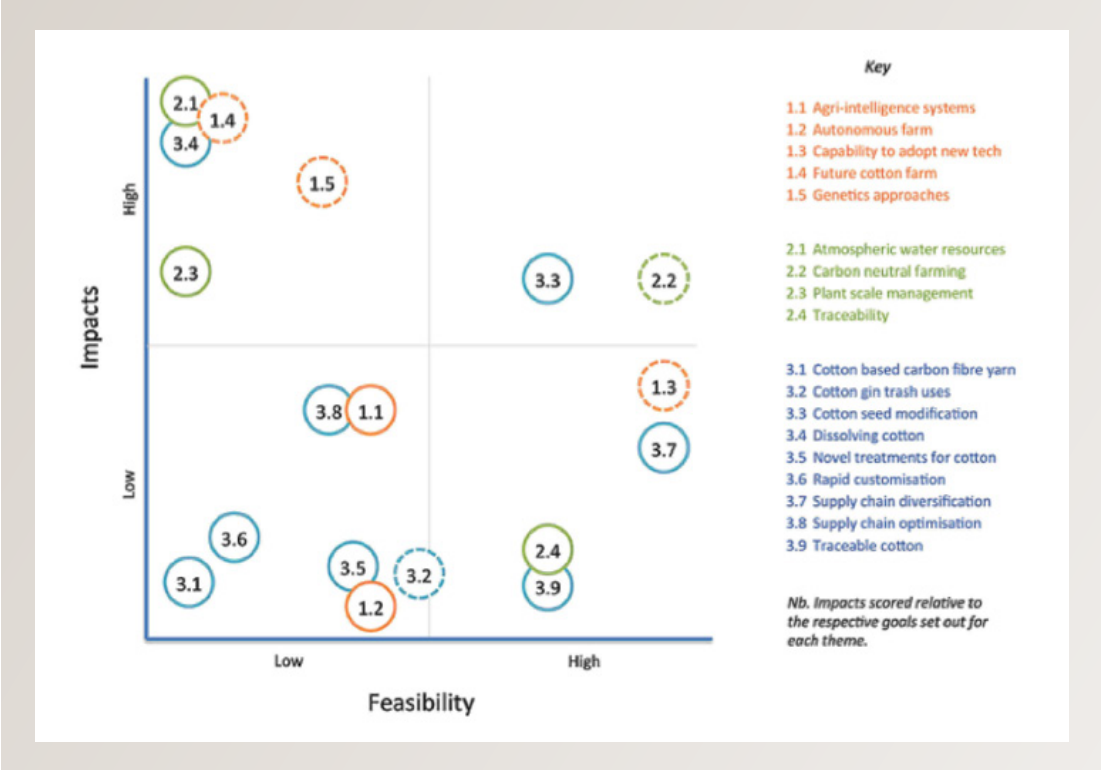


Figure 12 Feasibility by impacts assessment by cotton industry participants

It is important to note that almost all of the opportunities that were ranked low impact by the participatory design workshop were actually proposed as high impact tractable opportunities by the expert panels. Indeed around $1.4 billion worth of opportunities appraised by the expert panels sits in the low impact zone of Figure 12.

Managing for Transformation

Planning and Monitoring Impact Pathways

Impact pathways describe the series of results and outcomes that coalesce together through action of time and networks to deliver impacts (changes that can be measured on the triple bottom line). Planning and monitoring of impact pathways is important to understand the risks, barriers and opportunities that may be encountered along the way, how they interact, who should be involved and why, and what might motivate them.

The process can also be very informative for funders, researchers and industry participants as it can help surface assumptions, ideas and constraints that otherwise lurk without confrontation and disturb efforts to coordinate and share horizons.

Finally, the value of the discourse alone and how this can help to bring the relevant parts of the innovation system together. Ongoing robust discourse continually tests assumptions and value propositions and ensures as much as possible that different people in different organisations are working towards the same goals. There are four key high-level aspects to successful impact pathway planning and monitoring:

- **Leadership** focused on improving investment choices, the effectiveness and efficiency of activities and quality of knowledge translation and adoption. Promoting the benefits of change and modelling positive behaviour related to impact processes is a key aspect of the strategy.

- The **Capability** of staff and research providers empowers them to talk about benefits of their cotton research, not just the activities and outputs from projects. A capability for better informed decision making to accelerate delivery of benefits and maximise their expected value.

- A **Culture** focused on performance will embrace the mobilising force of goals specified in social, economic and environmental terms that the organisation aims to achieve.

- **Systems** that enable definition, measurement and analysis of CRDC progress not only for accountability purposes, but also for planning and review to accelerate performance.

Further information including a methodology for planning and monitoring performance against outcome targets is available[5,6].

[5] Barr, S. 2011. Performance Management Blueprint.
[6] Barnett, P. & Harch, B. 2012. Monitoring outcome performance. Technical Report EP125816. CSIRO Sustainable Agriculture Flagship.

Opportunity Portfolio Management

We take for granted factors affecting our business such as changing political, institutional, market, economic, social and environmental. We also accept that selecting high impact projects in the early stages is very difficult to do.

'If at first the idea is not absurd, then there is no hope for it' (Albert Einstein)

With a clear and well-understood set of desired impacts and the knowledge that the industry and research landscape is ever changing it is important to have a nimble and adaptive approach.

One way to achieve this adaptive approach is to have an opportunity pipeline or a register of opportunities cross-referenced with impact planning and monitoring such that the potential impacts of opportunities in the pipeline can at regular gates be assessed against target impacts.

A pipeline should also consist of a series of stages, each of which further qualify opportunities for greater investment and a reduction in associated risk.

Gates need to be carefully considered and rigorously applied to ensure that the pipeline is lean while opportunities are not missed through poor timing or drafting. An example preliminary gate would be feasibility, where opportunities are studied to ensure it's possible they could be successful, that the return on investment is appropriate and the impacts are plausible.

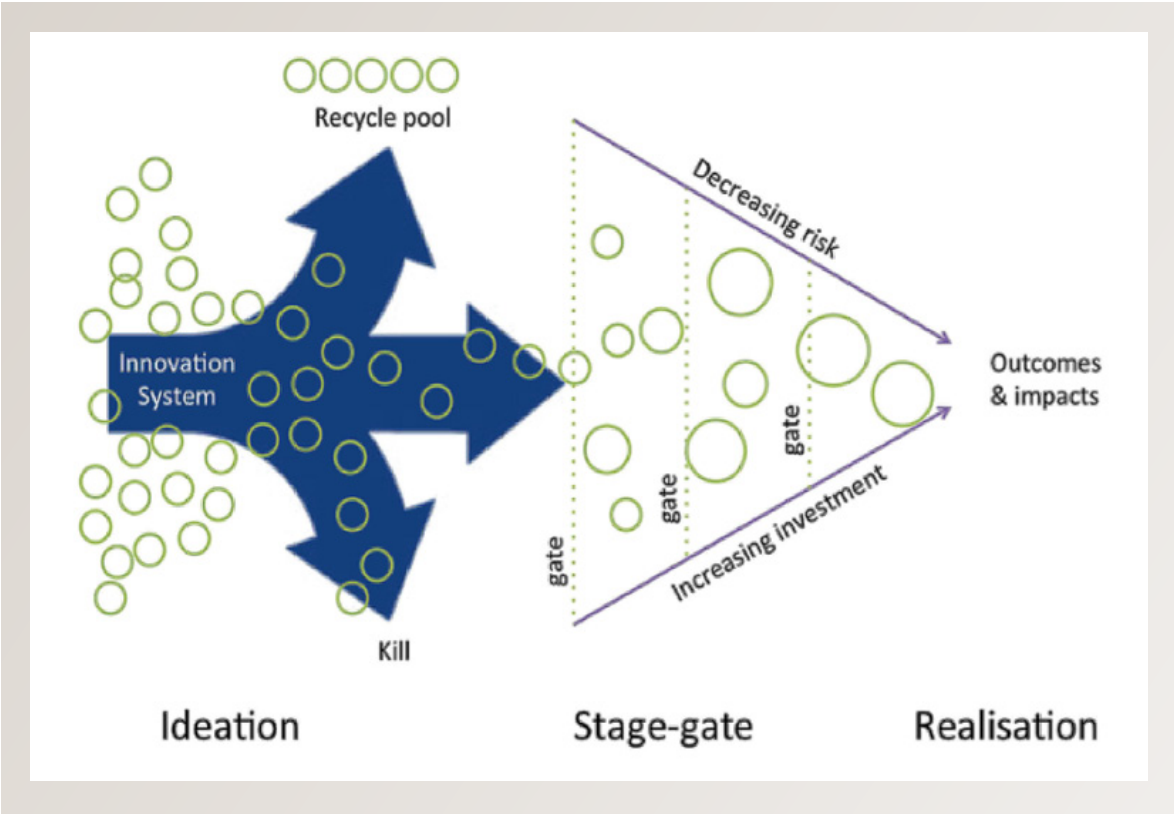


Figure 13 Managing a portfolio of opportunities through an opportunity pipeline

Through the nature of this process many more opportunities will be considered than proceed to full completion. As circumstances change in the world, opportunity prioritisation will also need to change.

Ideas and opportunities can and should be harvested from diverse areas at any stage and held to account on the same metrics and forecasts once in the portfolio. Additionally, opportunities presenting to a gate may be killed, sent back to the previous stage, put on hold or progressed to the next stage.

Rejection of ideas or early stage projects on the basis of a known and shared impact pathways supported by metrics and targets will be more palatable and community building for research and outcome partners and should remain the focus of decision making.

However, it is important to pair this transparent decision making model with strong and appropriate governance and lean gates. Having the right people involved as gatekeepers and appropriately lean levels of documentation at each stage will ensure time spent on preparing materials for gates is not overly burdensome[7].

Participatory Research

Conventional approaches to research have delivered a wealth of social, economic and environmental improvements to our everyday lives and continue to have an important role in the innovation system.

However, approaches are also needed that allow researchers to get closer to the problems they are trying to solve and deeply understand all of the associated barriers, risks and opportunities. Approaches such as those that allow land managers to co-create and contribute to new knowledge and expertise can help steer research to the most impactful areas.

The following diagram shows the relationship between different approaches to research and innovation. One dimension has the left half representing an 'expert-mindset' where end users are thought of as reactive informers of the research process, and the right half representing the 'participatory-mindset' where end users of research are also co-creators and participants in the research process. The other dimension has the top and bottom half representing industry and research led approaches to research respectively.

[7] Cooper, R. 2012. How companies are reinventing their idea–to–launch methodologies. Research Technology Management March—April 2009, Vol. 52, No. 2, pgs. 47-57

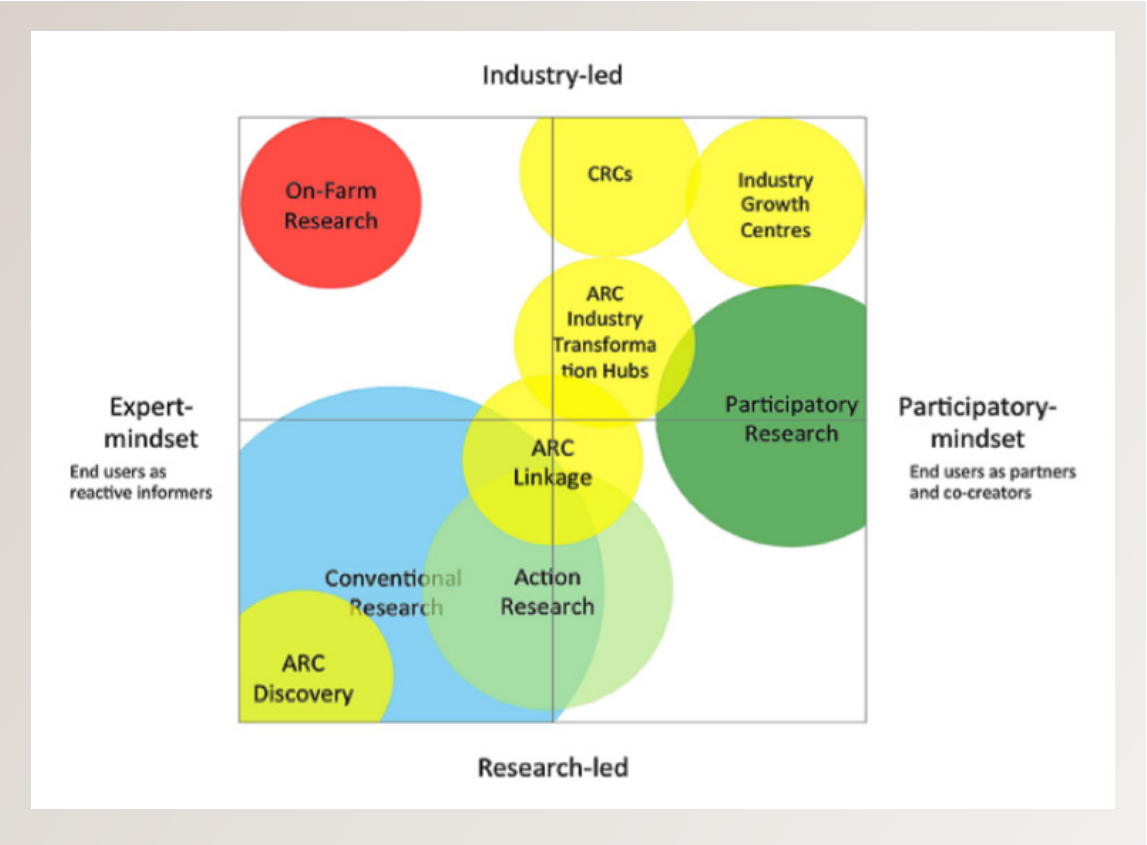


Figure 14 Approaches to research and innovation[8]

Participatory methodologies for undertaking research have gained much traction in developing countries, health and medical research. In contrast with conventional research, participatory research engages the community that would benefit from the research in the design, prioritisation and execution of the research. This approach has been demonstrated to reduce the occurrence of inappropriate recommendations because the people for whom the research is being done are regarded as co-creators that bring highly relevant knowledge and understanding into the project at every stage.

[8] Diagram framing inspired by Sanders, L. 2008. An evolving map of design practice and design research. ACM — Interactions — Volume XV.6

Conclusion

This report illustrates the significant opportunities ahead of the cotton industry in Australia. The opportunities that remained in scope for the CRDC through the process offer an estimated $4 billion per annum in economic impacts in 2014-15 dollars. This does not include additional impacts including market access, environmental and social impacts which could significantly improve this return.

The themes of analysis used to look into the future of the Australian cotton industry included Profitable Futures, Sustainable Futures and Competitive Futures. These themes shared a number of common trends:

- An increasingly challenging global fibre market where total fibre demand is increasing, as is market competition from natural, blended and synthetic fibres.
- Societal and demographic changes including increased expectations for cotton's sustainability performance and growth in Asian markets.
- Increasing rate of innovation bringing new technologies and new business models to agriculture and the fibre market.
- Resources required to produce cotton are becoming more expensive and production conditions more variable.

From these trends a number of significant opportunities have been identified including many that are strongly linked to the long-term success and transformation of the cotton industry in plausible ways. One example is the development of Agri-intelligence Systems and Autonomous Farming to drive the profitability and sustainability of the future cotton enterprise. Another example is the dissolution of cotton which, if successful, could completely transform the cotton supply chain, and the objectives of the cotton production system.

Key next steps for the CRDC include development of first stage projects for selected opportunities and the adoption of an opportunities pipeline management approach to ensure that risk and investment are being managed appropriately to maintain the probability of transformation in a cost effective way.

Finally, it will be important to continue building an industry culture that values open and fair appraisal of new ideas and expertise as well as participatory approaches that engage research and industry in the journey to a better future for cotton, together.

Appendix A: Profitable Futures Theme Briefing Paper

- Profitable Futures is focused on profitability of the farming enterprises that grow cotton – the production system. Profit is defined here as revenue less expenses in production up until the cotton leaves the farm gate.

- Profitability is at the core of the Australian cotton industry and is required before any other innovation can be achieved.

- The high variability of Australian cotton production is largely due to rainfall variability. While there are deep rooting cotton varieties that do better in drier areas and times, water shortages can impact on fibre quality and yield. Rainfall after the boll (protective capsule containing the cotton seed and fibre) has opened can also lead to decreased quality.

- At a global scale price spikes provide opportunity for synthetic man-made fibre producers to compete for market share. At a more local scale variability of Australian cotton supply may hamper efforts to generate stable relationships with cotton lint buyers.

- Australia holds the record of the world's highest average yield at 1779 kg/ha. Lint yields of Australian cultivars during the last 30 years have increased by 1.8% per year. Yield gains have been attributed to genetics (48%), management (28%) and cultivar x management (24%).

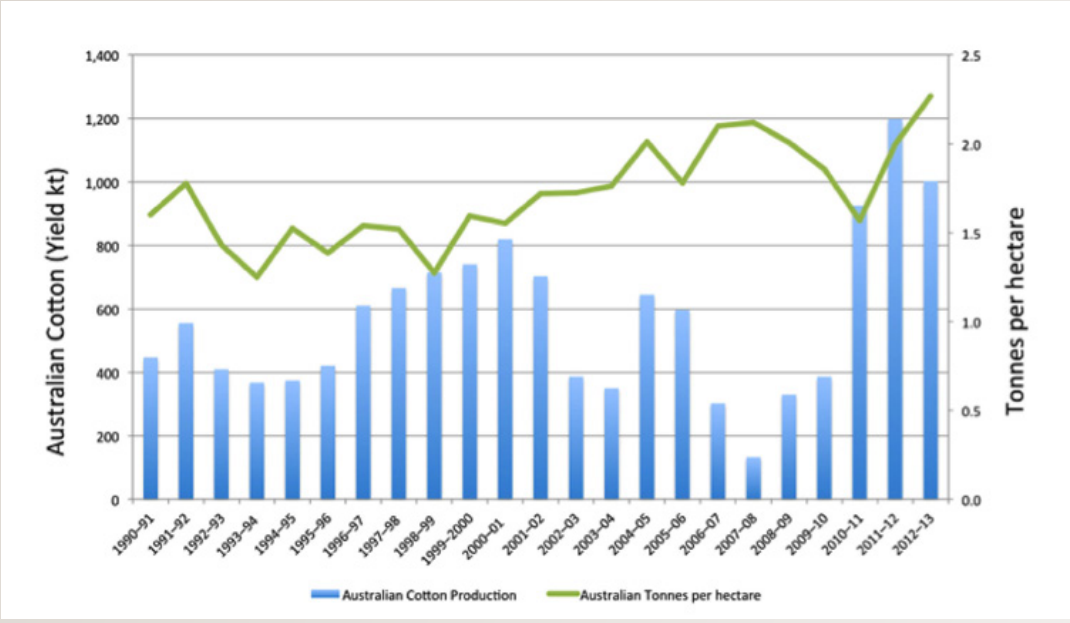


Figure: Australian cotton lint production (ABARES, 2013)

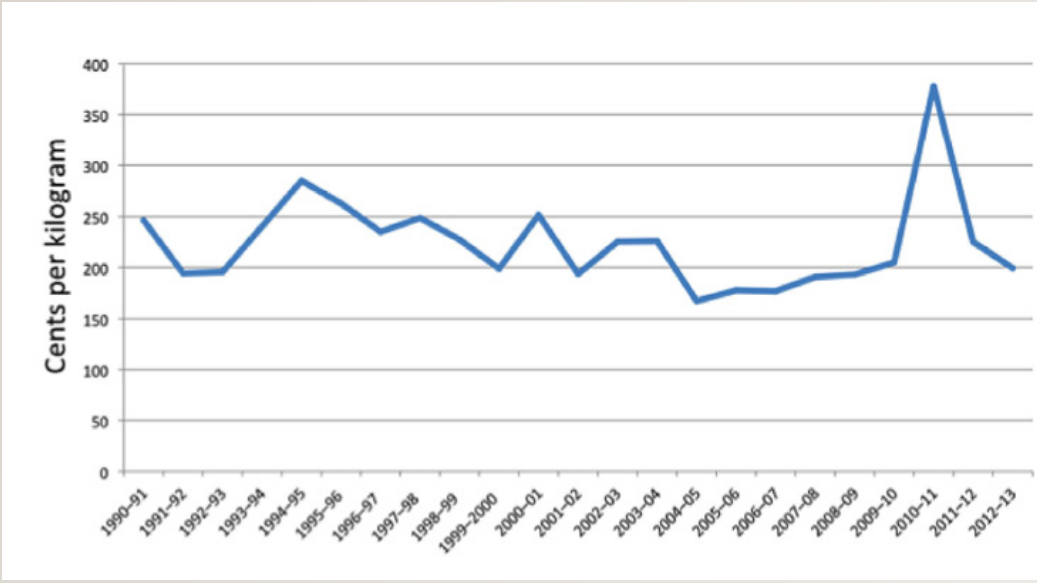


Figure: Australian base price for raw cotton (ABARES, 2013)

- Over time the price of cotton has varied substantially. A 2006 survey found 95% of Australian cotton producers had attempted to manage price risk at some time. Some Australian financial institutions offer derivatives including futures contracts. Other strategies include storing cotton on farm and waiting for a better price (Ada et al, 2006).

- The price paid for inputs by Australian farmers has been increasing while the terms of trade have remained somewhat stable. Of the inputs used by Australian farmers fuel, electricity, fertiliser and labour have in recent times increased substantially and sometimes associated with high volatility (Boyce, 2013; ABARES 2013).

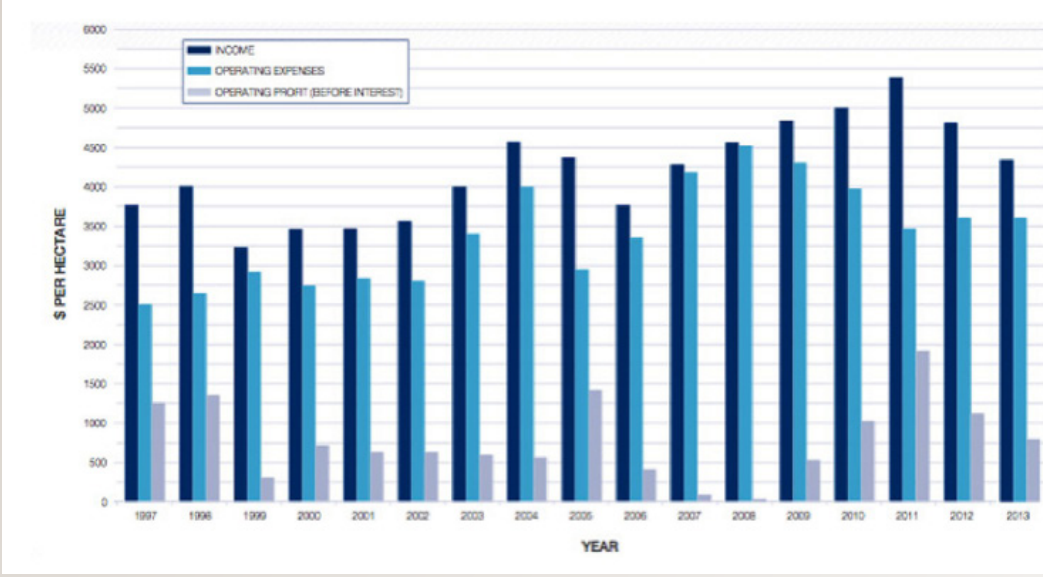


Figure: Comparison of average income and expense items for landholders (Boyce, 2013)

- In addition to input prices and yield volatility due to climate variability the following factors can also be significant determinants of profitability:
    - The price paid to cotton growers for seed cotton
    - Continuity of supply as important to securing customer relationships and branding
    - Supply chain factors and responsiveness to changing customer demands
    - Climate change is expected to have an impact on the area over which cotton can be grown with increases in extreme weather further contributing to yield volatility
    - Access to agricultural information is growing in Australia. As the diversity of connected devices and sensors grows and their cost falls the opportunity to leverage this information in decision making on farm is increasing.
- Data science integrates several disciplines including mathematics, statistics, information engineering, pattern recognition, risk and uncertainty modelling and computing. The multinational agriculture company Monsanto recently acquired a data science company, Climate Corporation, for $1.1bn, which may indicate a new focus on information to drive more efficient deployment of their products. To what extent would farming decisions be improved with better information about risk and uncertainty? What value could be added through the integration of market, climate and biophysical information?
- The use of robotic technologies that integrate real-time computer vision, sensing and communication can reduce the requirement for humans in repetitive, difficult, unpleasant or hazardous work. At present machinery and equipment are designed around humans. What would farming machinery look like without humans? What input efficiencies could be gained in the cotton production system? Robotics demonstrate potential in various industries by enabling new processes that weren't possible as well as replacing current labour practices.

Appendix B: Sustainable Futures Theme Briefing Paper

- The sustainability of Australian cotton should be viewed from perspectives of social, economic and environmental considerations. There are also some key cross cutting sustainability issues such as technology, global cotton initiatives, climate change / extremes and biosecurity threats. The diagram below outlines some of the key sustainability issues as identified by the Cotton Futures Workshop, December 2013. There are complex connections and tradeoffs that exist between many of these sustainability elements.

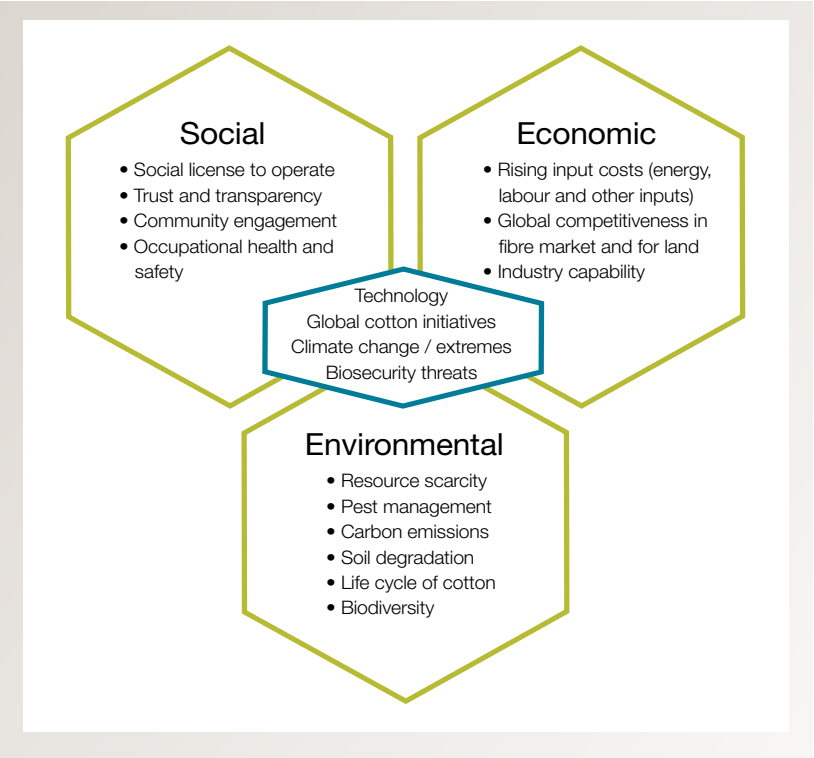


Figure: Influencing factors on sustainability of Australian Cotton (adapted from Cotton Futures Workshop 2013)

- The impacts and interactions of the cotton industry (both positive and negative) on the conditions of society and environment should also be considered at a number of scales.
    - Enterprise condition: understanding the full 'footprint' of a cotton growing enterprise in terms of carbon, water and landuse. What are the direct on-farm impacts for soil, water, fauna and flora.
    - Catchment and regional condition: understanding how cotton growing enterprises together are interacting with the off farm ecosystem and communities, rivers and catchments.

- National or industry condition: understanding the impacts and trade-offs of industry and government policy. Considering the future of national environmental accounts and Australian society.

- The challenge of understanding these interactions becomes more difficult with the transition to increasingly multifunctional landscapes that are required to deliver diverse agricultural production, ecosystem services, aesthetic and other values. Who should participate in that conversation, what outcomes are important and how are decisions made?

- A current effort to settle on a series of sustainability indicators is a positive step that the cotton industry is making to measure and manage its impacts on society, economy and environment. The cost of ongoing monitoring and analytics along with a program logic that links the measures with shared aspirations and goals will be important factors to consider.

- The diagram below illustrates a simple snapshot of the cotton supply chain. The supply chain can be characterised as long and complex with a diverse set of end products processed from cotton lint and seed.

Figure: Cotton Supply Chain (Adapted from EIF, 2009)

- Australian cotton is considered a premium product on the global market. Cotton prices are variable and input prices paid by farmers have been putting pressure on profitability. However, cotton is a major source of regional economic activity where it is grown contributing 30-60% gross value regional agricultural income in those areas (Roth, 2009).

- When compared with the average Australian farmer, cotton growers are younger and have a higher level of education. Deaths in the cotton industry are very low and workers compensation claims for accidents have been falling. Social capital in the cotton industry is high and well supported by institutional and network arrangements (Roth, 2009)

- In the last decade Australian cotton growers have made significant improvements in the management of natural resources. Over that time, water use efficiency has been improved by around 20% and there has been a reduction in insecticide use for Bollgard® crops (of 82%) and herbicides (of >80%) (Roth, 2009). Further improvements would be advantageous to the industry's sustainability credentials.

- The global cotton industry is still subject to negative attitudes from broader society and potential end users regarding its environmental credentials, particularly with respect to water. The graph below indicates at least an interest from the general public in the relationship between cotton and water.

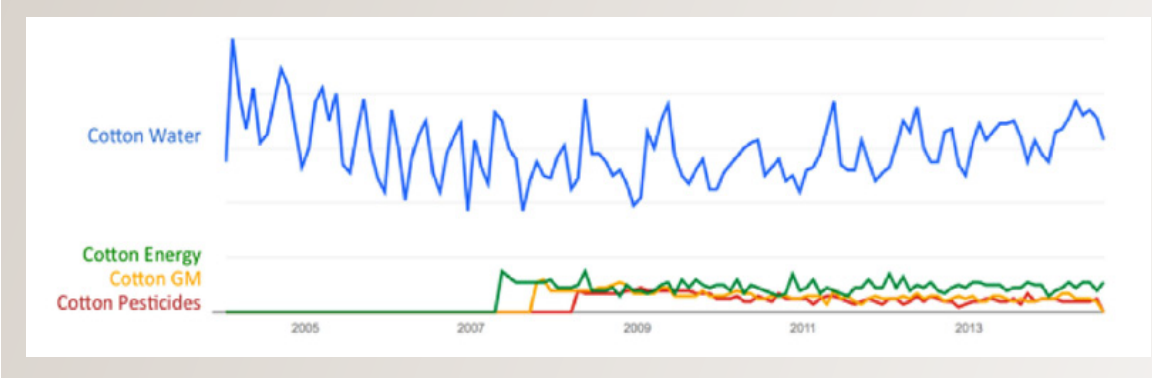


Figure: Relative frequency of cotton related Google search terms

- The growing demand for organic products including organic cotton occurs in a market place where the difference between the least sustainable and most sustainable conventional cotton is not well understood.

- The consumer is increasingly demanding greater transparency with respect to social and environmental impacts of products and services (Hajkowicz et al, 2012). The consumer of tomorrow will be more cautious with respect to the conditions and treatment of workers as well as sustainability of the production and supply system.

- Communities are also increasingly aware of their power and potential influence on the production systems around them. Take for example, the 'Lock the Gate' campaign against Coal Seam Gas.

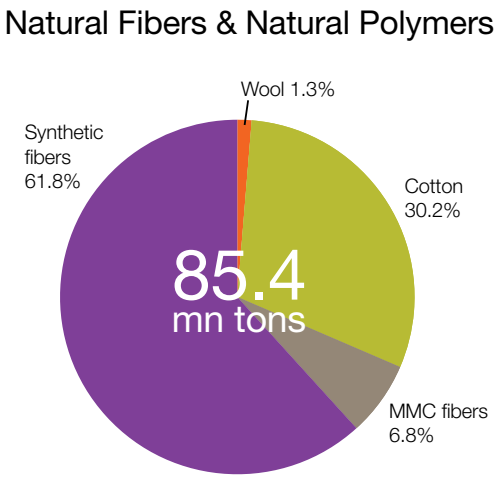
- Notable international efforts to produce more sustainable cotton include Cotton LEADS which is a joint program between Australia and United States of America. Another program with greater reach is the Better Cotton Initiative; recently it was agreed between Cotton Australia and the Better Cotton Initiative that certified myBMP cotton qualifies as Better Cotton. What communication with the supply chain and consumers about MyBMP would help sustain Australian cotton?

- Should sustainability of the cotton industry in Australia take a systems thinking approach that embraces the entire value chain from cradle to grave? Should our definition of sustainability include what the Australian cotton industry can, should or would do to improve the sustainability of cotton growing areas in other countries? Could recycled cotton assist in filling the cellulose gap or smoothing production swings?

- Operating sustainably on all of these dimensions has been identified as critically important by the industry and is one of the CRDCs five high level goals for its R&D Plan 2013-18.

Appendix C: Competitive Futures Theme Briefing Paper

- Cotton accounted for roughly 30% of the global fibre market in 2013.



- The term 'Cellulose Gap' refers to natural fibre demand in excess of maximum global cotton output. There are varying estimates as to what this gap will be filled by including synthetics, cellulosics and increased cotton production.

- In the last decade Australian cotton has accounted for between 0.6 and 4% of global lint production with the variability largely due to swings in Australian cotton production from as low as 132,000 tonnes in 2008 to as much as 973,000 tonnes in 2012.

- Australian cotton is regarded as a premium product on the global market. Further improvements in certain quality aspects (eg. strength, elongation) based could build on this perception.

- The variability in volume and quality of cotton supply from the Australian cotton crop is potentially a significant issue in the development of brand loyalty.

- Given Australia makes up only a small proportion of global cotton production it is worth considering the end user demand for Australian cotton. The graph below shows the relative Google search frequency over time for four origins and organic cotton.

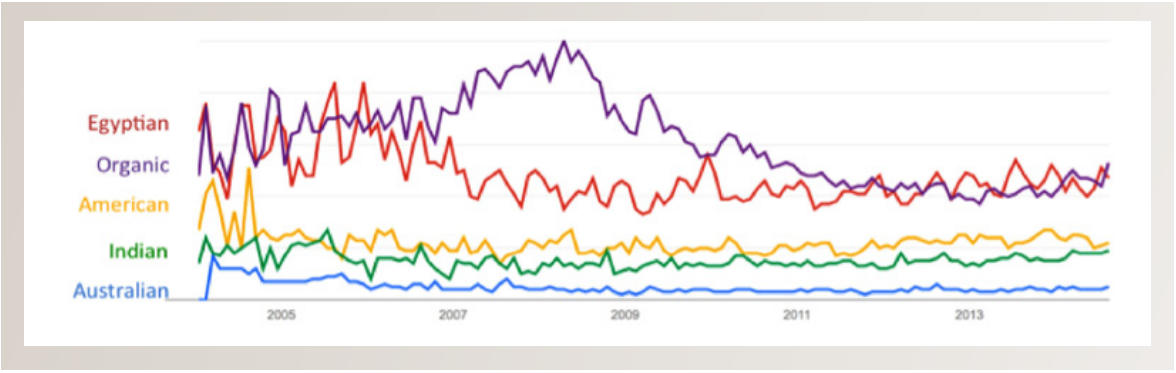


Figure: Relative Google search frequency for selected types of cotton

- This figure requires further investigation but does suggest global consumer interest in origin-specific cotton is much lower for Australian cotton as compared with other selected origins.

- While absolute cotton fibre demand has been increasing the share of total fibre demand occupied by cotton has been declining in recent decades.

- The innovation cycle for manmade fibres is demonstrably faster than that for cotton fibre. Cotton varieties can take 14 years from concept to seed available in commercial quantities. Manmade fibre manufacturing innovation and development of new materials is accelerating with the application of computational methods.

- Manmade fibre industry participants are rapidly creating and filling spaces in the textiles market. For instance, new products regularly appear that claim to provide comfort, health and safety functions for use in sports, automotive, health, electronics and more.

- Trends in demand for intelligent fabrics indicate a future where we will seek to measure and monitor things in our lives such as our homes or bodies for health or fitness applications.

- Petroleum and stationary energy are the major inputs in manmade fibres. New manufacturing processes and engineering advances are delivering significant reductions in the use of energy in the processing of synthetic and natural fibres. Additionally, growth in closed loop recycling and open loop recycling in fashion also contribute to considerably lower energy use.

- Beyond current woven textiles manufacturing processes there is a new generation of non-woven manufacturing technologies including 3D printing. 3D printing has the potential to significantly reduce the length and complexity of the supply chain in almost all existing cotton markets, and at the same time accelerate market cycles and deliver the means of mass customisation or agile manufacturing. In February 2014, Innocentive hosted a call for technologies that use cotton fibre as a printing material or substrate for 3D printing.

Table: Cellulose sources

Source	% Cellulose
Cotton	90
Switchgrass	70
Bamboo	60
Wood	40-50

- Cotton is known to be one of the purest forms of cellulose at more than 90%. This can be compared with other common sources of cellulose in the table to the right. Cellulose and nanocellulose may have a significant role in flexible and lightweight electronics in the future. In particular, cotton is already being deployed in electronics applications with broad application. For example, Power Japan Plus has developed a cotton-based battery that could be used in electricity grid management, home and transport.

- The adoption and recognition of standards is becoming more important in markets that seek greater clarity in the quality, sources and impacts of what is being consumed. While ethical standards have generally been the domain of the private sector, there is an increasing interest from Government (for example the European Union) in developing sustainable supply chains. The Better Cotton Initiative (BCI) is termed here an ethical standard because it concerns environmental and social conditions under which cotton is produced.

Figure: Converging standards in global cotton supply chain

- There are moves to have information accompany products along the supply chain. While there are good examples of companies meeting higher expectations through transparency and traceability, accepted information standards and associated protocols for transmitting ethical and quality performance information along the supply chain and in decision-making appear nascent.

Appendix D: Theme-Based Workshop Participation

In addition to Bruce Finney (CRDC Executive Director), Ian Taylor (General Manager R&D Investment) and Paul Barnett (Facilitator) the theme-based expert panel workshops had the following attendance.

Profitable Futures Workshop Attendance

Name	Organisation	Expertise
Amy Billsborough	Cargill	Cotton Marketing
Bronwyn Harch	QUT	Informatics
Charlie MacDonald	Telstra	Logistics and Manufacturing
Hamish Miller	Grower	Growing Cotton
Peter Fitch	CSIRO	Information Engineering
Stuart Whitten	CSIRO	Environmental Economist
Susan Maas	CRDC	Research Program Manager
Tristan Perez	QUT	Autonomous Systems

Sustainable Futures Workshop Attendance

Name	Organisation	Expertise
Alice Payne	QUT	Fashion Sustainability
Allan Williams	CRDC	Research Program Manager
Cathy Foley	CSIRO	Materials
Lillly Lim-Camacho	CSIRO	Supply Chains
Michael Battaglia	CSIRO	Sustainable Agriculture
Peter Haydon	Australian Pork Limited	Marketing

Competitive Futures Workshop Attendance

Name	Organisation	Expertise
Adam Best	CSIRO	Batteries and Wearables
Allan Williams	CRDC	Research Program Manager
Eimear McDonagh	Australian Cotton Shippers Assoc.	Cotton Marketing and Logistics
Jared Donavan	QUT	Interaction Design
Louis Kyratzis	CSIRO	Textiles and Nano
Rafael Gomez	QUT	Industrial Design
Simon Dunstall	CSIRO	Operations Research

Appendix E: Participatory Design Workshop Participation

The following people responded to confirm their attendance at the participatory design workshop.

First name	Surname
Steve	Ainsworth
Craig	Baillie
Mick	Bange
Paul	Barnett
Amy	Billsborough
Graham	Bonnet
John	Cameron
Sophie	Davidson
Jared	Donovan
Simon	Dunstall
Bruce	Finney
Peter	Fitch
Rafael	Gomez
Barb	Grey
Brendan	Griffiths
Juanita	Hamparsum
Bronwyn	Harch
Mark	Hickman
Jamie	Iker
Dallas	King
Helen	Klaebe
Louis	Kyratzis
Lilly	Lim-Camacho
Hamish	McIntyre
Hamish	Millar
Alice	Payne
Mark	Peoples
Tristen	Perez
Ruth	Redfern
Cleave	Rogan
Greg	Simpson
Ian	Taylor
Jane	Trindall
Stuart	Whitten
Allan	Williams
Lewis	Wilson

Designing a Future for Australian Cotton

CRDC Futures Program

Barnett Consulting

COTTON FUTURES

Australian Government
Cotton Research and Development Corporation