

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

May 2016

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BelTempo
NATURAL RESOURCE MANAGEMENT



Australian Government
**Cotton Research and
Development Corporation**



**Local Land
Services**
North West

Project: CRDC1502

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Development Corporation**

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Executive summary

Agricultural production, including cotton production, is an increasingly complex business requiring continuous adaptation to changing circumstances. Resilience thinking is an approach designed to understand a complex and changing operating environment and maintain capacity to manage future challenges. It is now being widely adopted globally to help communities, industries and governments alike deal with uncertain futures.

The Cotton Research and Development Corporation undertook this resilience assessment of the Australian cotton industry at multiple scales to better understand how to best adapt to change and identify critical threats and opportunities for the industry, and strategically target investment and resources. This resilience assessment is structured around the three scales of cotton production in Australia – the farm, the region and whole of industry.

The key assets, inputs, outputs and dynamics have been identified for each scale, with particular emphasis on identifying the major thresholds or tipping points that are potential risks the industry may need to manage in the future (specified resilience). The attributes of general resilience (capacity to cope with unknown and unpredicted changes) have also been assessed and the linkages between scales and the potential for cross-scale interactions are identified.

There are five key drivers of change acting across the Australian cotton industry. These are **demand, policy, climate change, climate variability** and **cotton price**. Potential shocks, which are a sudden spike in one of these drivers, relate to **climate change and variability, biosecurity, policy, price** and **social licence**. Industry leaders and growers need to be aware of the impact of those drivers, and of the changing nature, frequency or severity of shocks to better prepare and respond to them.

These drivers and shocks have the potential to push the Australian cotton industry towards identified tipping points, or critical thresholds, which if crossed lead to significant changes in system dynamics. At the farm scale, the critical thresholds identified are **water quality and quantity, soil health, farm profitability** and **habitat proximity**. **Network connectivity and function, infrastructure investment, native vegetation cover, water quantity and land availability** are critical thresholds at the regional scale. At the whole-of-industry scale, the critical thresholds are **social licence, network connectivity and function** and **research and development investment**. A case study based on an analysis of two cotton growing regions over the decade of the Millennium drought demonstrates the way in which growers and cotton growing regions respond to these drivers and thresholds in practice.

Based on this assessment and an initial review of potential intervention points, addressing **national research and development, regional water availability and infrastructure, farm profitability** and **farm water availability** thresholds should be the highest priority for interventions from a specified resilience perspective.

Modularity (the degree of connected/disconnectedness across the system) emerges as the priority general resilience attribute for the industry as a whole. A review of the existing sustainability indicators reveals the extent to which some of these can also be used as resilience indicators at various scales.

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Introduction

This report documents the findings of a resilience assessment of the Australian cotton industry. It draws together information from a range of sources, including grower and industry workshops and surveys, a literature review, local and expert knowledge and existing research.

Viewed through a resilience lens, the analysis of this information highlights where the industry could focus research and development effort to build capacity to prepare for future challenges and uncertainties. The report is about **preparing** for the future, not predicting it.

The assessment and this report are structured around the three levels or scales of cotton production in Australia – the farm, the region and whole of industry at a national scale. The key assets, inputs, outputs and dynamics are identified for each scale, with particular emphasis on identifying the major thresholds or tipping points that are potential risks the industry may need to manage in the future. The linkages between scales and the potential for cross-scale interactions are also identified.

The information presented is a snapshot of the industry and its current dynamics based on the best available information and reflecting industry perceptions of the critical issues it currently faces. There are, however, many knowledge gaps and unknowns. Undoubtedly, new challenges and unexpected issues will emerge in the future as the industry and the context within which it operates changes. Preparing for this unknown future and developing the capacity to manage these unknowns requires investment in a range of generic capacities (termed **general resilience**). The report also identifies areas in which general resilience is a strength or may be lacking.

CRDC's long term goal is that *the Australian cotton industry is the global leader in sustainable agriculture* and that *'Cotton is profitable and consistently farmers' crop of choice'*. The industry is striving to achieve a vision of *Differentiated, Responsible, Tough, Successful, Respected and Capable* by 2029¹. This resilience assessment is designed to support CRDC to achieve those goals through strategic effort and investment.

¹ Emergent Futures (2010) *Cotton Industry Vision 2029*. Report prepared for CRDC

Context for the project

Agricultural production is becoming an increasingly complex business. Major uncertainties about global economics and international markets, shifting national policies and social values, demographic changes, competition for key resources, rapid technological change and the impact of an increasingly variable climate mean agricultural industries must continually adapt to changing circumstances. Industries need tools and approaches that continually update their understanding of how they fit into this larger context and to develop and maintain the capacity to navigate the challenging times ahead.

Resilience thinking is one such approach that is now being widely adopted globally to help communities, industries and governments alike deal with uncertain futures (see [Appendix 1](#) for more about resilience thinking). This project uses a resilience assessment approach to develop a whole-of-system perspective that incorporates the economic, social and ecological dimensions of the industry, and how these interact and influence each other over time. Of particular importance is how the industry manages specific risks associated with key thresholds, and how it copes in the face of major expected and unexpected future changes and events (or shocks) such as droughts or market fluctuations.

By identifying key drivers and tipping points at each level, as well as the important linkages and feedbacks within and across these levels, resilience assessment provides a deeper understanding of the whole system, from the farm to the Australian cotton industry level.

Understanding the industry's capacity to cope with uncertainty and manage critical tipping points - where that capacity is well developed and where it is weakest - will allow the industry to target future research and development, planning, capacity building and extension activities to ensure all facets of the industry are best placed to cope with an uncertain future.

The specific aims of the project are to:

1. Complete a resilience assessment to identify where the cotton industry should direct its effort and investment in financial, human and natural resources to reach its long-term strategic goals.
2. Demonstrate the value of the resilience framework for the cotton industry to lead, adapt to change and identify critical threats and opportunities.
3. Review and assess the suitability of existing indicators for ongoing monitoring of industry sustainability in light of the resilience framework

Resilience thinking in brief

Resilience thinking is a globally emerging paradigm for understanding complex systems and therefore being able to manage them. Complex systems are characterised by having many components, with linkages and interactions between those components. The human body is an example of a complex system; no single part or organ could function on its own, nor is any individual part completely independent or in control, rather the connections and interaction between parts result in a functioning body.

In a similar way, the cotton industry is made up of many interacting parts that include biophysical components like water and soil, transport, financial and infrastructure systems, human skill and labour. It is the combination of these components and all the interactions and connections between them that make up the cotton industry system.

In a complex system, components are not just structurally linked, they are functionally linked, with changes in one component having flow-on effects to others. Relationships between components can be one-way (such as a driver 'pushing' parts of a system in one direction or two-way with **feedbacks** from one component back to another).

Feedbacks can be negative, in that they dampen the effect of one component on another, or positive, where they amplify or reinforce the effect of one component on another. They can occur directly (primary feedbacks) between two components or indirectly (secondary, tertiary) where the effect comes back through other components. These changes occur at different levels or **scales** and occur in cycles, sometimes in repeated though irregular patterns.

A complex system is hard to manage and plan for because interaction between its individual components, driven by external and internal forces, creates unintended change or forces parts of the system past thresholds from which it is difficult to recover.

Complex systems can be multilayered, so an individual farm, a region, ecosystem or industry can be considered an individual system or these may all be considered parts or subsystems of one larger multi-scale system. Understanding the linkages across these scales is important as changes at one scale can cause changes at others.

Resilience assessment and management seeks to identify major **thresholds** within the system that if crossed could lead to significant changes in the dynamics. Crossing an important threshold can trigger a shift in structure, function and feedbacks of the system, with the system then said to have changed 'state'. These different states are often described using state and transition models such as the example shown in Figure 1.

These models visually represent the key concepts and present the minimum information that explains the broad dynamics of relevance. Typically, there are costs or losses associated with a major change in state as the new 'alternate state' will produce a different set of outputs or substantially different levels of outputs. Thresholds occur on the key 'controlling variables' that support the function or process of interest, usually the ones generating the system outputs we are interested in (in this case cotton).

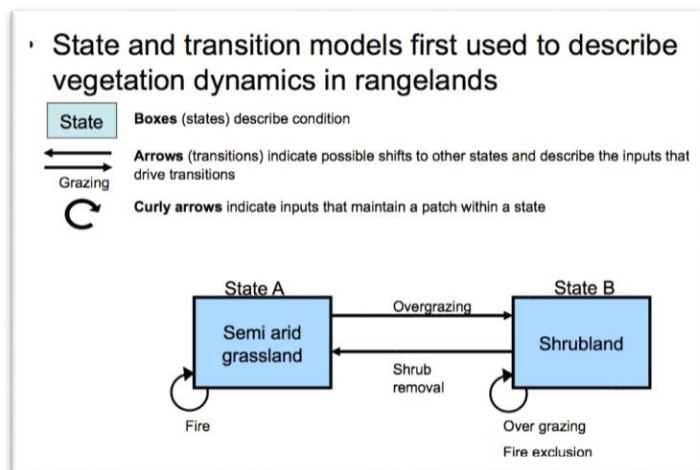


Figure 1. Example state and transition model for rangeland vegetation dynamics.

Managing thresholds requires that the key variables that determine the position of thresholds be identified and monitored. For example, the key variables associated with plant growth in an irrigated system might be the availability and quantity of water, the time when the water is available and the efficiency of the irrigation system.

Two important influencers in complex systems are drivers and shocks. **Drivers** are external sustained directional ‘pushing’ forces that act on parts of the system. If sustained for long enough, drivers create recognisable trends. An example of this relationship between drivers and trends in agriculture is the long-term decline in terms of trade for traditional commodities (driver) causing structural adjustment and aggregation of properties, resulting in a trend towards larger farms. Drivers usually cannot be managed from within the system.

Shocks, or short-term ‘spikes’ in drivers, can rapidly push systems close to or over major thresholds. Shocks vary in timing, length and severity, but commonly they are hard to anticipate, and their magnitude is mostly unknown and hence difficult to plan for. Examples of shocks in agricultural systems include extreme climatic events, shifts in input and output prices, new diseases, pests or weeds and changes in policy. The Indonesian live cattle export ban is an example of a policy shock.

Complacency and human nature are major factors in determining the level of impact a shock has on any part of a system. Individual and collective memory is an important aspect of this. Some types of shocks, e.g. fire, droughts and floods, occur at semi-regular intervals and yet they are often perceived as a totally unexpected event. The response from the community and government can at times reinforce this perception.

Managing resilience is about developing the capacity to manage and maintain distance from the key thresholds by preparing for and learning from expected and unexpected changes and events. The goal of resilience management is to stay within a ‘safe operating space’, defined by the key thresholds of the system, so the system produces the range of outputs and benefits valued by people.

Information

For more information on the origins of resilience, along with key terms and concepts, go to [Appendix 1](#). For more information on the resilience assessment process, go to [Appendix 2](#). For a review of recent international and Australian peer reviewed literature, including Australian case studies of the application of resilience thinking, go to [Appendix 3](#).

Developing a systems view of the Australian cotton industry

The Australian cotton industry – resilience snapshot

The Australian cotton industry has been able to remain resilient in the face of a range of major drivers and shocks and has avoided major thresholds at the regional and industry scales.

At the property scale, worsening terms of trade and drought have caused the turnover of individual business, although the total number of growers remains relatively constant. The resilience of the industry at different scales can be attributed in part to the inherent attributes and flexibility of the system. Cotton is an annual crop that requires minimal regional processing, is relatively cheap to transport and can be grown as part of a diversified farming system.

The industry has benefited from major technology advances, has strategically invested in R&D and training and skill development, and is benefitting from the legacy of past decision making about allocation and pricing of water resources and provision of public infrastructure such as dams as well as favourable periods of climate and commodity prices. The legacy of many of these structural and functional dynamics will mean the industry remains resilient in the shorter term.

The major challenge for the industry is to remain resilient in the in the medium to longer term because of the impact of issues such as the rapid increase in alternative fibre technologies, rising input costs and climate change. In particular, cotton price (and hence business viability) and water availability at a range of scales are major issues the industry must manage in the face of an increasingly complex set of drivers.

For this project we have defined the system of interest as the chain of cotton production from paddock, to processing and delivery of processed cotton into the manufacturing market, thus excluding the manufacture, sale and distribution of cotton-derived products.

This system incorporates the assets and natural resources, inputs such as labour, technology and capital, hard infrastructure such as irrigation, communication and transport networks and soft infrastructure such as social networks. Within this system, there are obvious sub-systems at different scales; farms, cotton growing regions and the national or whole-of-industry scale. Each of these scales has its own characteristics and internal dynamics meaning they are recognisable subunits of the larger system but with strong connections to the scales above and below.

Key drivers such as policy and cotton price influence dynamics within and across these scales creating trends that slowly push part of the system towards or away from thresholds. Shocks (spikes in drivers) such as severe drought or a disease outbreak can potentially push key variables across thresholds causing significant changes in the way parts of the system function and reducing desired outputs.

Table 1 (over page) is a brief summary of the key drivers, assets, thresholds, inputs, outputs and controlling variables of the Australian cotton industry at the farm, regional and whole-of-industry scales.

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

Although this assessment looks specifically at these three scales, it is important to note that the Australian cotton industry sits within the international cotton industry and Australian agriculture, which is in turn part of a global agriculture (see Figure 2).



Figure 2. Range of scales in the Australian cotton industry.

While the farm, region and industry scales interact as part of the whole cotton production system in Australia, there are some important differences that emerge at different scales. In particular, the objectives of the farm scale cotton production are fundamentally different to those at the regional and whole-of-industry scales. While at the regional and industry scales the objective is to keep the cotton industry going, at the farm scale it is to remain viable as a farm. This is an important difference as the whole Australian cotton industry is only resilient while farmers make the decision to grow cotton.

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

Table 1. Australian cotton industry. Resilience assessment matrix across three scales.

	Drivers	Assets	Critical Thresholds	Alternate states	Trends	Inputs	Internal "driver" Influencer	Output
FARM	Price, Climate variability, Policy	Water (ground and surface) Soil Capital Habitat Energy Infrastructure	Quantity & Quality Health Profitability Proximity	Producing/ Capable/ Incapable	Declining/stable water quality Declining/variable water availability Declining/stable soil health Increasing input costs Increasing habitat fragmentation Increasing cotton yield Increasing energy costs	Fertiliser Herbicide Skills & expertise Seed Pesticide Beneficial biodiversity Off/other farm income Technology inc. GM Labour	Biosecurity	Cotton crop
REGION	Demand, Climate variability, Climate change, Policy	Regional networks Regional expertise Regional infrastructure Native Vegetation Water Land	Connectivity & Function Infrastructure investment Cover Quantity Quantity	Producing/ Capable/ Incapable	Declining public investment in R&D Declining public investment in infrastructure Declining/variable native vegetation cover Declining/stable water availability	Energy Skills & expertise Labour		
INDUSTRY	Demand, Climate change, Policy	Natural Resource Base Networks Knowledge and tech Services Suppliers Infrastructure	Social Licence Connectivity & Function R&D investment	Broadscale/ Niche/ None	Declining natural resource base Increasing global fibre demand Increasing market expectations Declining public investment in R&D Declining terms of trade in Australian Agriculture Declining public investment in infrastructure	Capital (Levy) R&D	Policy	

Thresholds

Thresholds can interact within and across scales leading to knock-on or cascade effects through the system. An obvious example of a cascade within the cotton industry is water availability, which if reduced as a result of climate change, would lead to less cotton production at the farm scale for an extended period. This could result in investment in regional infrastructure such as ginning and irrigation capacity falling below critical levels required for infrastructure renewal and replacement, leading to larger scale system disruption.

Figure 3 illustrates the linkages identified between key thresholds within and between scales and in the social, economic and environment domains. As an example, a key variable or measure for water quality is pH; the threshold is the **level** of pH at which cotton production is reduced.

Thresholds are being continually influenced by drivers and shocks, so at any particular time the system will be operating close to some thresholds and further away from others. In many cases thresholds are not identified until they are crossed. Systems are more subject to change when they are at risk of crossing multiple thresholds.

The interaction of thresholds across scales highlights the particularly critical role that profitability at the farm scale plays in the cotton system as a whole. If profitability thresholds are crossed by enough cotton producing businesses in a region there is potential for significant immediate and longer term knock-on effects and feedbacks to other parts of the system.

This interaction also highlights the following:

- The profitability threshold at the farm scale interacts with the research and development threshold at the whole-of-industry scale. This is because research and development is funded, in part, by grower levies. The application of research and development findings then assists cotton farms with increased profitability and interacts with the social licence threshold.
- The social licence threshold impacts on the regional scale infrastructure replacement threshold, which in turn affects the profitability threshold at the farm scale, and on the regional natural resource thresholds.
- At the farm and region scales there are a number of interactions between the natural resources of land, water quality, water quantity, soil health, habitat and native vegetation cover. These in turn impact on the profitability threshold at the farm scale and the social licence threshold at the whole-of-industry scale.
- Networks, particularly at the regional and whole-of-industry scale, impact on the thresholds associated with research and development, natural resource management and profitability.

Each threshold is explored in more detail in the report.

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

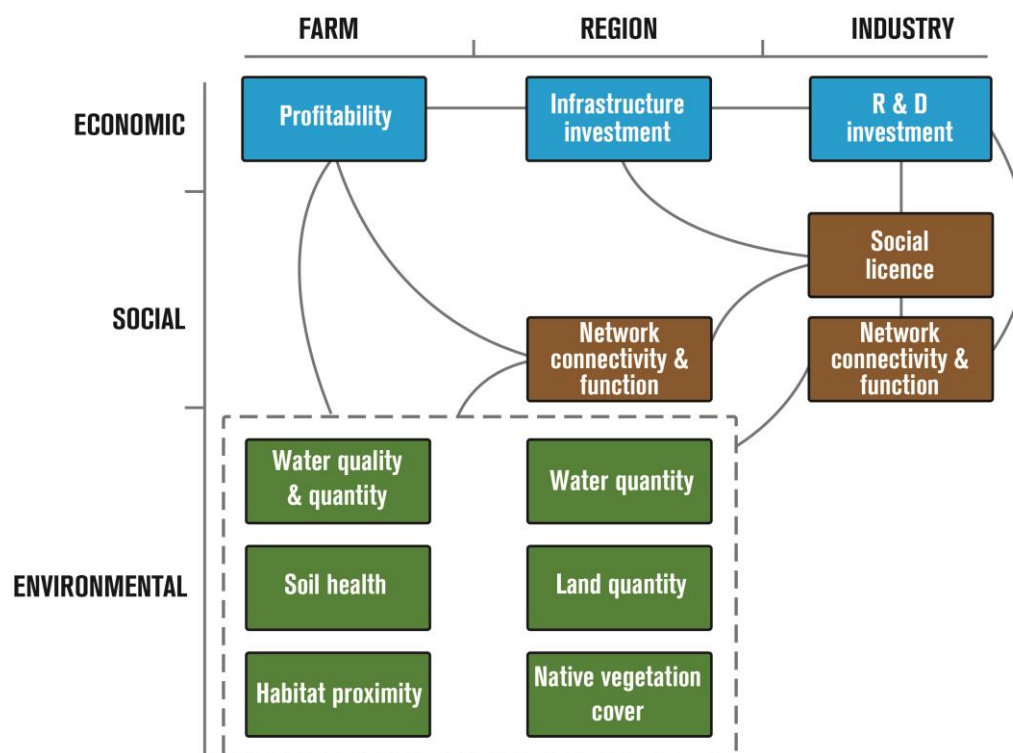


Figure 3. Interaction between thresholds across scales.

Production is central to the resilience of the cotton industry. It has implications for many critical thresholds at a range of scales such as national research and development, regional infrastructure and farm profitability. While there is currently a steady trend of increasing yield, production levels are volatile. The trend for increasing yields is expected to continue in the short to medium term, which helps to keep the industry away from critical thresholds at the farm scale. The overall volatility of production across the industry as a whole, however, is driven by drought and prices. This volatility demonstrates the responsiveness and capacity of the industry to respond to external drivers. Volatility in the national cotton production also means the industry will be vulnerable to crossing thresholds at the whole of industry and regional scale particularly when there is a sustained period of low production.

What does this mean?

Two major thresholds of potential concern regarding water and profitability are not fixed, meaning that the threshold varies over time, space and scale. There are also strong interactions between the two. The social licence threshold is also not fixed and interacts in complex ways with both the natural resource and profitability thresholds, which has implications for high input cotton production. Once a business or part of the industry crosses one or several of these thresholds a new set of dynamics and feedbacks is established and the system quickly changes to a new state.

To date, the industry and individual businesses have been able to avoid these thresholds through a range of deliberate strategies, new technologies and good fortune. Changes in the intensity of drivers (e.g. energy price) and frequency and magnitude of shocks (e.g. drought) mean the future for cotton production presents some challenges.

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

Based on the known controlling variables associated with each threshold, the best management intervention points can be identified and most suitable indicators selected (see Figure 4). The industry can then better assess and prioritise trigger points for intervention and prioritise them for monitoring and evaluation at a range of scales. Triggers are an agreed point at which an action is taken based on the measure of a particular indicator.

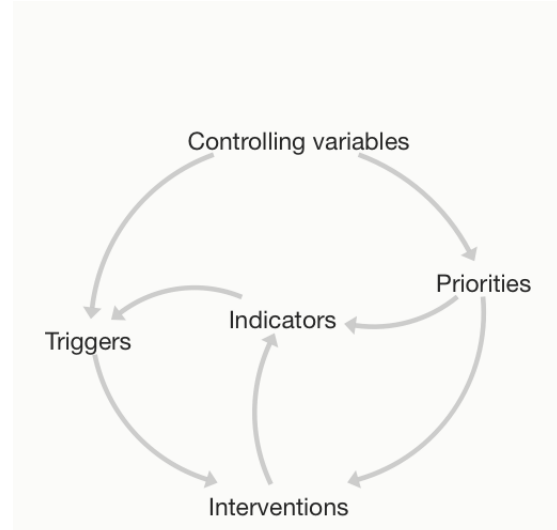


Figure 4. Relationship between controlling variables, indicators and interventions.

Drivers

There are five key drivers acting across the Australian cotton industry that influence the system at different scales (See Table 2).

Table 2. Key drivers acting on the Australian cotton industry.

Scale	Driver
Industry	Policy Demand Climate change
Regional	Policy Demand Climate change Climate variability
Farm	Policy Price Climate variability

The drivers operate at different rates, e.g. prices for some inputs and cotton show fast dynamics and can fluctuate over days or weeks, as can the weather (climate variability). In contrast, policy at the farm scale and climate change at the regional and industry scale has relatively slow dynamics that apply slow pressure over time (see Figure 5). Importantly, most drivers cannot be influenced from within that scale of the system. The only exception is policy, which can be influenced indirectly through lobbying, particularly at the whole-of-industry scale, although that is rarely fully effective at removing or modifying a driver enough to negate its influence on the system. Internal drivers, or influencers, are those that can be acted on from within that scale. For the Australian cotton industry these are biosecurity issues (pests, weeds and disease) at the farm scale, and policy at the industry scale.

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

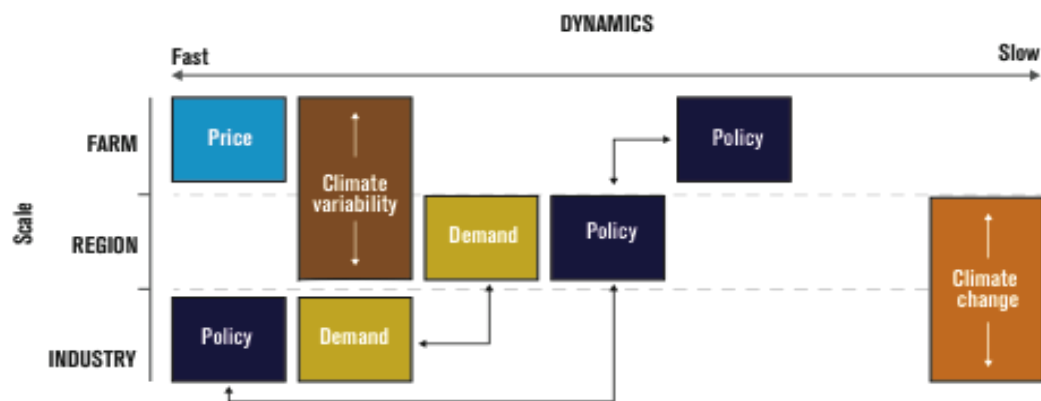


Figure 5. Influence and dynamics of drivers across scales in the Australian cotton industry.

What does this mean?

The drivers identified affect the industry and individuals differently, changing the dynamics and creating fluctuations in the relationships between parts of the system. Many drivers cannot be managed directly at one particular scale, rather they can only be indirectly influenced (e.g. lobby for policy change and communicate to influence public perception) or be adapted to (e.g. diversify to reduce the impact of commodity price or adopt technology to improve terms of trade).

The industry scale is best placed to influence issues such as policy, public perception and technology in a systemic way. Individual growers have most influence over the daily management decisions at the farm scale, particularly biosecurity issues.

Declining terms of trade, i.e. stable or falling output price compared to escalating input costs - mainly water and energy - are major drivers that will shape the industry in the short term (1 to 5 years). With the potential for new policy decisions to affect water and other natural resources and responses to climate change, and with the possibility of increased competition and changing consumer trends in the medium term (5 to 20 years), it is clear the industry faces major sustained challenges from large external drivers.

The industry needs to be aware of and prepare for when drivers become synchronised. For example, a combination of increased energy costs, increased fertiliser costs, lower water availability due to drought or sudden policy changes and reduced commodity prices, as has happened in the past, is likely to place individual cotton businesses under major financial pressure. While this is already well understood by the industry, paying close attention to drivers is likely to build the industry's capacity to manage and respond to their impacts.

It may be most important to pay attention to major long-term trends in drivers such as terms of trade, energy prices, climate, consumer preferences and technology, as these are unlikely to change in the short term. If the trends in these drivers are pushing parts of the system towards major thresholds, the industry should make understanding these drivers and how to respond and adapt to these changes a priority.

Shocks

Shocks are drivers that peak either negatively or positively in magnitude or intensity for a brief period before returning to normal levels. Shocks identified through the consultation workshops, literature review and other inputs that could affect the Australian cotton industry are listed in Table 3.

Table 3. Potential shocks of relevance to the Australian cotton industry.

Shocks	Example
Climate	Drought, flooding, hail, extreme heat or cold events
Biosecurity	Pests, weeds, disease
Policy	Policy decision, new regulation, tax changes
Price	Input costs, cotton price
Social licence	Major shift in public perception and opinion, consumer preferences or values

What does this mean?

Shocks push parts of systems close to or over thresholds. It is hard to plan specifically for shocks, but some can be anticipated and planned for more easily than others, e.g. drought.

Changing perceptions held by growers to make them aware of the nature of shocks and strategies to prepare and respond to them is important in helping growers to better conceptualise and manage for some shocks. Similarly, the frequency or severity of some known shocks may be changing, so growers need to adjust their thinking about them. As an example, climate change is likely to influence the variability of climate so that droughts, floods, hail and rainfall will all occur more often and with more intensity in some regions and, as a result, change when pest and disease outbreaks might occur and how severe they might be. In pointing out the potential effects of climate change, it is worth noting that the geographic zone of cotton production overlaps with climate change impact zones (see pages 17 to 18 for details).

Monitoring, scenario planning and other future focussed activities have an important role in preparing for shocks and increasing capacity to anticipate, manage, reflect on and learn from experience. Reflecting on questions such as how people coped during the last shock, what they learned and what they would do differently this time are all important.

Documenting assumptions and running scenarios to learn rapidly and reduce recovery times are key to sustaining general resilience. For an assessment of general resilience go to pages 55 to 60.

Assumptions

An important factor that affects how well the industry is able to prepare itself for and respond to shocks in the future is the nature of the assumptions that it has made about itself and the environment it operates in². These assumptions provide insights into the industry's current state, but can also undermine future efforts if they are not acknowledged and regularly tested.

From surveys and industry workshops, key assumptions identified that underpin the cotton industry's confidence in its ability to cope with future changes and shocks have emerged as follows:

- technology will continue to develop so that it can meet the natural resource management, biosecurity and fibre characteristics challenges in future
- the industry as a whole is a coherent system with similar objectives and values at the range of scales
- social licence to grow cotton will persist and allow the industry to fully use the technological developments as they occur and to continue to access the required natural resources, i.e. land and water
- government (public) funds will continue to be invested in renewing and maintaining infrastructure
- best practice land and water management can offset issues of resource scarcity.

² Barnett, P. (2014) *Designing a Future for Australian Cotton*. Report by Barrett Consulting for Cotton Research and Development Corporation, Australia

Industry scale

The resilience process was applied to each scale to identify elements such as assets, drivers and trends as a way of identifying priorities for how the cotton industry might respond to future challenges. Table 4 is a summary of this process for industry scale.

Table 4. The resilience process applied at industry scale.

Drivers	Assets	Critical Thresholds	Alternate states	Trends	Inputs	Internal "driver" Influencer	Output
Demand, Climate change, Policy	Natural Resource Base	Social Licence	Broadscale/ Niche/ None	Declining natural resource base	Capital (Levy)	Policy	Cotton Crop
	Networks	Connectivity & Function		Increasing global fibre demand	R&D		
	Knowledge and tech Services	R&D investment		Increasing market expectations (environmental and social)			
	Suppliers			Declining public investment in R&D			
	Infrastructure			Declining terms of trade in Australian Agriculture			
				Declining public investment in infrastructure			

Assets

There are a number of assets that interact at the industry scale. The three major ones are the **natural resource base** (land and water), **national networks** and **knowledge/technology**; services, suppliers and infrastructure are also significant assets but are of lesser importance for intervention at this scale given the absence of associated critical thresholds. Each of the assets is explored in Figure 6.

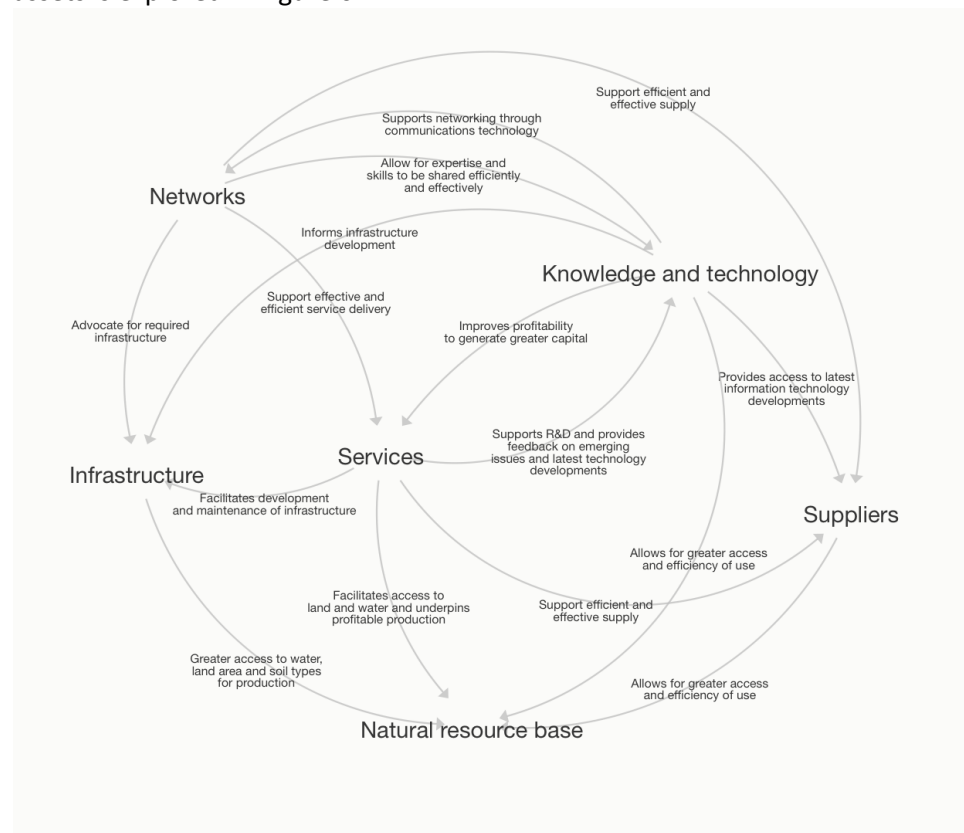


Figure 6. Conceptual model of assets interacting at the whole-of-industry scale.

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

Natural resource base

This includes adequate, suitable agricultural land and water to support cotton production.

National networks

The cotton industry has highly developed and effective networks, particularly those underpinning research and development, policy advocacy and marketing. These networks include national research and development organisations, industry representative and marketing organisations and formal and informal grower networks.

Their existence underpins the fact that the cotton industry is well connected at all scales and between scales. This connection allows for effective communication in the industry and is in part responsible for its ability to respond quickly to issues and take advantage of opportunities. This is also important for general resilience.

Knowledge and technology

Research and development contributes to knowledge about cotton growing, processing and marketing, and networks then facilitate synthesis and dissemination of this knowledge. Policy is the most significant driver acting on this asset along with demand through consumer preferences. Knowledge and technology are also important in addressing the challenges presented by climate change (the other key driver at the whole-of-industry scale) and its impact on growing conditions.

Services

The industry is supported by a number of services such as financial services (including forward selling), marketing, merchants, consultants and classers.

Suppliers

Suppliers provide important inputs, such as seeds, fertilisers, fuel, chemicals and biotechnology, which contribute to maintaining the cotton industry.

Infrastructure

Hard Infrastructure is fundamental to cotton, which is an export crop. Particularly important are transport (national road and rail) and export (port) facilities.

Output

The output at the whole-of-industry scale is a **national cotton crop** and associated products.

Australia is one of about 76 cotton producing nations. In crop year 2014-15 cotton production in Australia amounted to around 2.3 million bales, so for that period Australia was the seventh largest producer of cotton worldwide. Australia's crop is a small percentage of that of the major producers: China (8%), India (8%) and the United States (14%). Depending on the Australian season, it is about the 4th largest exporter of cotton lint behind USA, India and Uzbekistan. Almost all Australian cotton lint is exported³. Year-to-year variation in Australia's exports can be large and change rapidly, e.g. there was a 76% increase in exports in 2009-10 compared to 2008-09, largely because of the breaking of the drought.

³ <http://cottonaustralia.com.au>

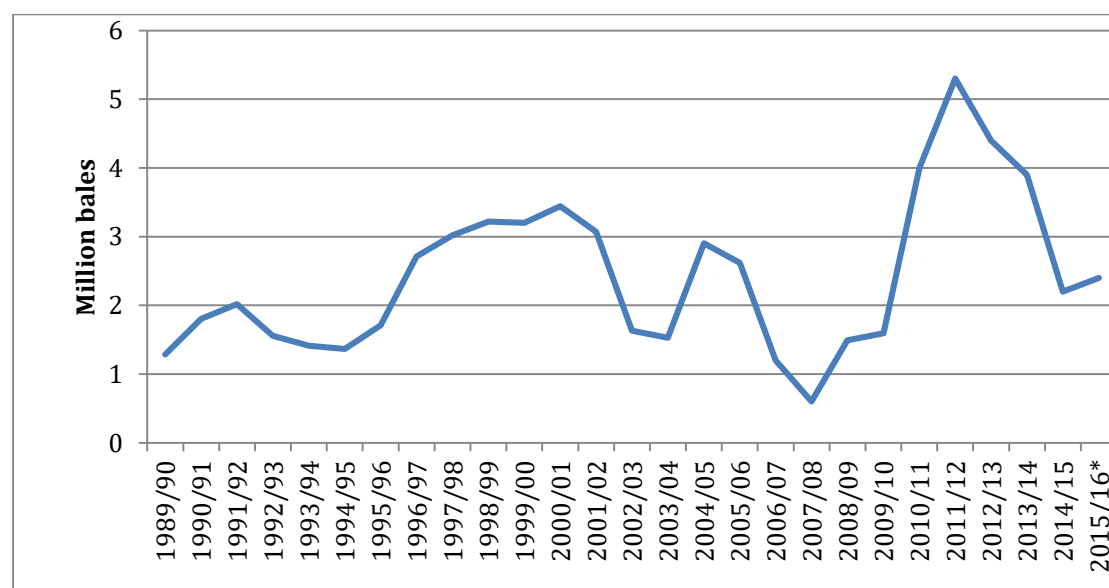
Resilience Assessment of the Australian Cotton Industry at Multiple Scales

In crop year 2013-14 cotton production in Australia amounted to around 900,000 metric tonnes. It is a significant crop in Australia with a value for cotton lint of \$1.9 billion in the year ending June 2013⁴.

Over the last 25 years, Australian cotton production has fluctuated from under 1 million bales (2007-08) to over 5 million bales (2011-12). As seen in Figure 7, production showed a general upward trend until the Millennium drought, which saw production drop significantly. This is explored in more detail as part of the drought case study in this report (pages 81 to 98). Production from 2011 to 2014 has broadly resumed the upward trend before the drought, while 2016 is expected to be below trend at around half 2013-14 levels.

From the CRDC *Sustainability Report 2014*⁵, the following comments were made about Australian cotton and average annual production for the last five years (2009 to 2014):

- *Australian cotton is viewed worldwide as having an excellent quality fibre. It is used to produce high quality yarns for use in the woven and knitted apparel sector.*
- *Irrigated planted area was 354,775 ha. Dryland planted area was 96,074 ha. Irrigated crop yield was 9.85 bales/ha [2236 kg/ha]. Dryland crop yield was 4.09 bales/ha [928 kg/ha]. Total production was 881,463 metric tonnes [3.9 million bales] The gross value of production was \$2 billion. Average cotton area per farm was 495 ha.*



*Estimate

Figure 7. Australian Cotton Production⁶.

Cotton seed meal (313,000 t), cotton seed oil (109,000 t) and cotton oilseed (1,881,000 t) are also significant outputs from the Australian cotton industry⁷. In the 2014 figures, about half the meal and 10 per cent of the oilseed is exported. Australia exports cotton seed to Japan (crushed and cattle feed), Korea (crushed), China (crushed) and the USA (dairy feed) depending on parity price and the value of the Australian dollar. Little if any oil is exported.

⁴ ABS 7503.0 - Value of Agricultural Commodities Produced, Australia, 2012-13

⁵ http://www.crdc.com.au/sites/default/files/pdf/CCC14003%20Sustainability%20Report_LOW%20RES_O.PDF

⁶ Australian cotton production data from <http://cottonaustralia.com.au/cotton-library/statistics>

⁷ 2013 figures from <http://www.indexmundi.com/agriculture/>

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There is also a small but important market in growing seed for planting⁸. All seed used by Australian growers is grown domestically⁹.

Inputs

The inputs are **research and development** and **capital** through the research levy.

Drivers

The drivers at the industry scale are **demand**, **climate change** and **policy**.

Demand

Demand for cotton is a critical driver for cotton production and without it there would be no incentive to produce a cotton crop. Demand is also a key driver in that consumer preferences drive research and development. This is because consumers express preferences for particular types of cotton, which the industry must then provide. As well, trends in artificial fibres and cotton production internationally create competition in the market for Australian cotton and cotton by-products.

Climate change

At this scale the impact of climate change as a driver is that it can influence where cotton can be grown as a result of making an area more or less climatically suited to the crop. Climate changes can increase the costs associated with cotton production, e.g. in adaptation measures.

Climate change projections for core cotton growing areas in Australia from the Darling Downs in Queensland to the Central West in NSW (called Central Slopes Region) to 2030¹⁰ predict that the climate will get warmer and there will be more hot days and warm spells. There is no clear pattern for rainfall until later this century when extreme daily rainfall events will be more intense. They also predict an increase in climate extremes.

Climate analogues for three towns in cotton growing areas further illustrate these changes¹¹. The climate analogue tool matches the proposed future climate of a region of interest with the current climate experienced in another region using annual average rainfall and maximum temperature (within set tolerances). For current greenhouse gas emissions, to 2030, analogues for the following locations are:

- Dalby – future climate matches present climate of Roma, Lightning Ridge and St George
- Narrabri - future climate matches present climate of Roma, Chinchilla and Dalby
- Griffith - future climate matches present climate of Condobolin, Hay and Cobar.

In this context, the assumption can reasonably be made that pests, weeds and diseases that are common in the analogue locations are likely to become prevalent in the target locations.

⁸ e.g. Cotton Seed Distributors <http://www.csd.net.au/>

⁹ source, ICAC, 2011 - quoted from <http://cottonaustralia.com.au/cotton-library/fact-sheets/cotton-fact-file-the-australian-cotton-industry>

¹⁰ www.climatechangeinaustralia.gov.au

¹¹ www.climatechangeinaustralia.gov.au

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Projections for cotton growing regions are as follows¹²:

- Average temperatures will continue to increase in all seasons (*very high confidence*).
- More hot days and warm spells (*very high confidence*).
- Fewer frosts (*high confidence*).
- Average winter and spring rainfall to decrease (*medium confidence*).
- Changes in summer and autumn are possible but unclear.
- Increased intensity of extreme rainfall events (*high confidence*).
- A harsher fire-weather climate in the future (*high confidence*).

Cotton yields in the major cotton growing regions will vary more under projected 2030 conditions as a result of predicted climate change for irrigated cotton. Dryland cotton yields will also vary more and some decline is predicted.

Given that cotton is often farmed as part of a mixed farming enterprise, it is important to note that annual pasture production and other crops such as wheat and sorghum will also be impacted by climate change. Pasture production is likely to be reduced¹³, and more periods of lower rainfall events will reduce opportunities to plant other crops¹⁴.

See [Appendix 4](#) for more detailed information of predicted climate change impacts.

Policy

Policy encapsulates national policy and associated legislation, including natural resource management, infrastructure, export, research and development and energy.

Policy is another key driver that acts on research and development, e.g. the extent to which government supports it philosophically and financially. An important function of policy is that it drives research and development, which supplies knowledge and technology (a critical asset as outlined below). Policy also occurs as an internal driver, i.e. something that can be influenced from within this scale, as well as system driver that operates on the cotton industry at all three scales.

Related to this is the fact that funding support for many industries, which was originally largely public, has shifted so that it is now largely private. This has significant implications for what research and development issues are funded.

For a summary of previous work undertaken by the cotton industry to identify drivers and shocks operating at the whole-of-industry scale and more information on the drivers of change identified during the literature review for this report, refer to [Appendix 5](#).

Internal drivers of change

The key internal driver of change, or influencer, at the industry scale is **policy**.

At this scale, policy is not only an external driver, but also an internal driver of change that can be, and is, acted on from within the system. Skills and expertise include advocacy as well as research and development.

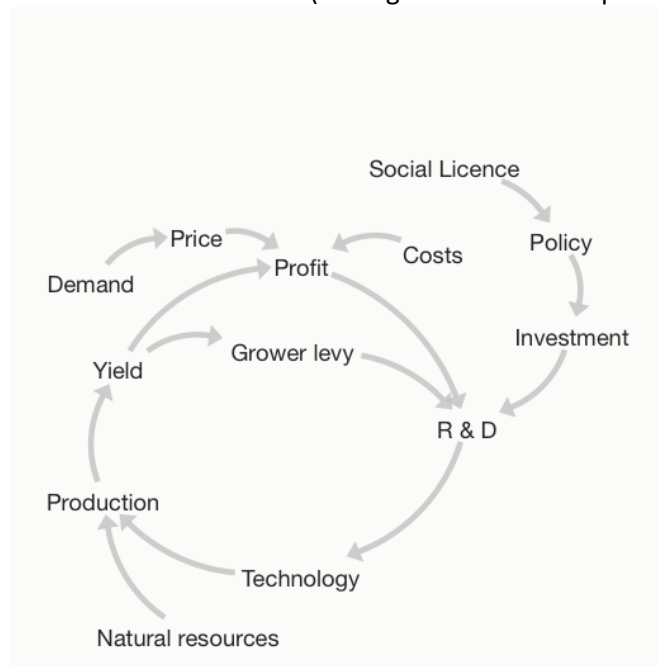
¹² It is important to note that on an annual and decadal basis, natural variability in the climate system can act to either mask or enhance any long-term human induced trend, particularly in the next 20 years.

¹³ Local Land Services, 2015. *Climate Change in the North West Local Land Services Region: An Addendum for the Transitional Regional NRM Plan for the North West LLS Region*. p. 17

¹⁴ Local Land Services, 2015. *Climate Change in the North West Local Land Services Region: An Addendum for the Transitional Regional NRM Plan for the North West LLS Region*. p. 14

- research and development investment (knowledge and technology)
- social licence
- network connectivity and function.

There are a number of elements to knowledge and technology in relation to resilience at an industry scale. Some important limits (or thresholds) exist around the amount of investment in research and development, and there is a threshold around knowledge supply staying in front of threats and costs. In effect, investing in research and development helps to maintain the profitability of the industry. Conversely, there is also a point at which a drop in investment would mean that research and development organisations and infrastructure could not be maintained (see Figure 8 for a description of this relationship).



There are potential feedback loops and interactions between the critical assets underpinning cotton production at the national scale in particular in relation to level of production and investment in research and development, ongoing resistance and development of biosecurity threats such as insect pests. This is buffered to some extent by international research and development undertaken by the major suppliers, which supports overall production efficiency of Australian cotton. This is not enough on its own, however, without local investment, adoption and adaptation. This local adaptation and adoption is important at the smaller scales of cotton production¹⁵.

¹⁵ Cotton Info Team (2013) *Cotton Pest Management Guide 2013-14*. Cotton Info Team
Cotton Info Team (2014) *Cotton Pest Management Guide 2014-15*. Cotton Info Team
Cotton Info Team (2015) *Cotton Pest Management Guide 2015-16*. Cotton Info Team

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The national cotton production system relies on high inputs and high levels of technology for both infrastructure and biotechnology. These variables can push the national cotton production system towards high input/high productivity (current state), integrated niche industry (which would require adaptation), or a low-input cotton production system (transformation).

The controlling variable for the knowledge (research and development) threshold is investment (from all sources). As long as the total invested in research and development is enough to offset future costs and threats the threshold is not crossed. It is important to note that a large part of current research and development funding comes from the grower levy. This coupling of significant research and development investment to production (through the levy) exposes its supply to other drivers and shocks that influence production (such as climate change, climate variability and policy).

Social licence

Social licence is a product of trust, community values and perceptions and is most obviously expressed through policy settings (see Figure 9). For the cotton industry, social licence to operate relates to resource use, water and land use in particular, pesticide and chemical use in specific geographical areas, as well as GMO use and labour (fair trade/working conditions) more generally. As part of maintaining its social licence, Cotton Australia has recently joined two international sustainability partnerships, the Cotton LEADS Program and the Better Cotton Initiative.

The point at which policy settings change is an expression of a shift in social licence or community values. This can be triggered by an event, new technology developments or new information, which then shifts public perceptions and values to the point where policy and regulations are changed (see Figure 10). This means that at an industry scale, the sustainability of the cotton production system can be influenced by public perception driving policy and planning.

There are two types of thresholds associated with social licence. These relate to the potential states for the cotton industry as a whole. The first threshold is one where cotton growing is restricted in some way, such as where and how it can be grown, and the second is where cotton cannot be grown at all. It is most likely that the first threshold would be crossed before the second unless some significant public risk was identified.

The controlling variable for the social licence threshold is socio-political support for cotton growing. Public preference to allow, regulate or otherwise constrain the industry is driven by values and perceptions.

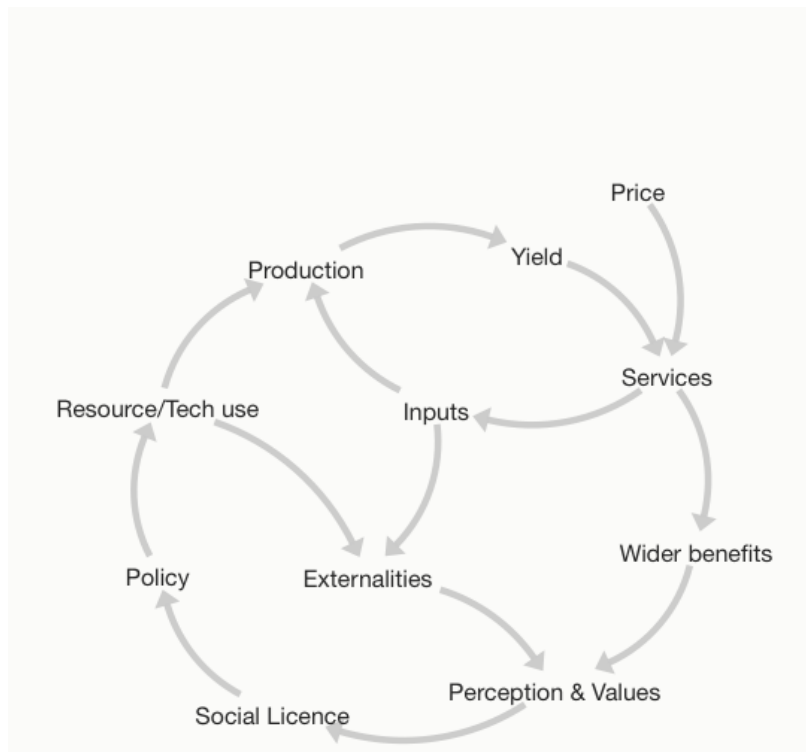


Figure 9. Relationships between social licence, values and policy.

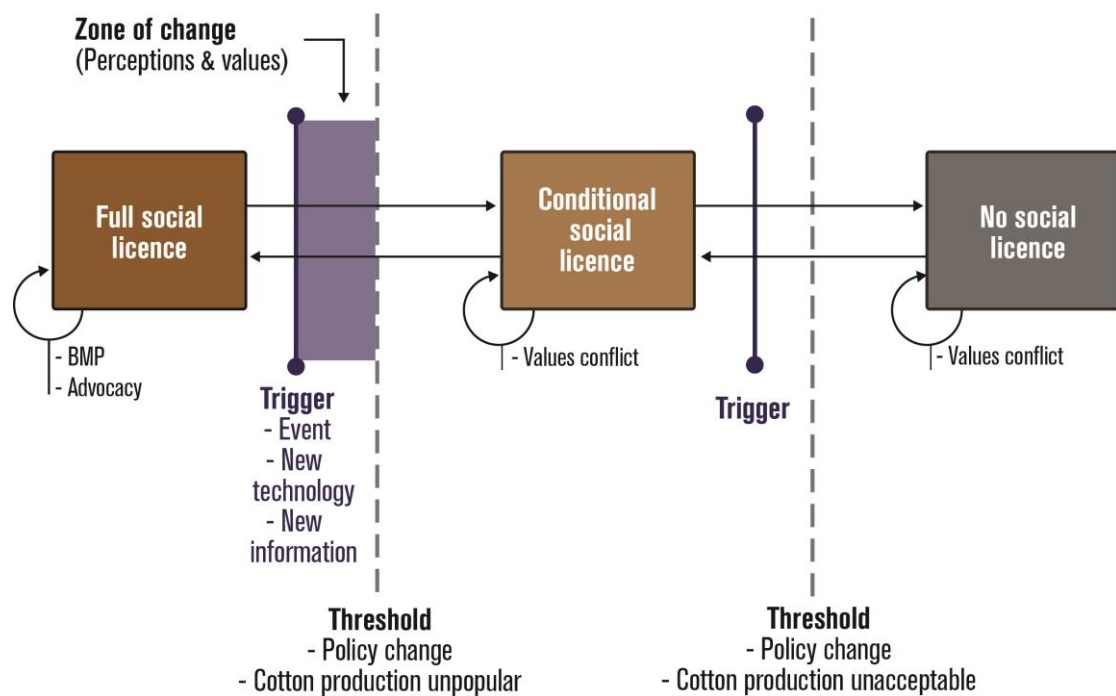


Figure 10. Different states in relation to social licence in the Australian cotton industry.

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Network connectivity and function

National networks include research and development, policy advocacy and marketing. These networks are used particularly by national research and development organisations, industry representative and marketing organisations and grower groups.

A threshold has been identified for the degree of network function and connectivity. Connectivity is a combination of network reach or breadth of connections and density or number of connections. It is network function (efficient and effective flow of information) which is most important.

There are four potential states identified based on the high or low level of density and reach each of which have different characteristics¹⁶. These states are as follows:

- Networks with high density allow for good information exchange and learning as well as enhanced diffusion of innovations. High density can also mean, however, there is the potential for systems to become super connected and brittle.
- Low density of connections can mean more diverse management practices, low risk for lock-ins and global coherence but it can also result in limited spread of information.
- Networks with a high degree of reach have the advantages of being able to access distant information and more ability to respond to changes, and they can bring together different stakeholders to better match ecological or social boundaries and can extend over the long range. The spread of contaminants or negative ideas, however, can be enhanced over large distances by these networks, also as a result of their connected nature.
- Networks with low reach allow for the formation of coherent and efficient clusters and can limit the impact of disturbances. The flipside is that this makes distant information inaccessible and can make it hard to re-establish networks where they have ceased.

Modularity (an attribute of general resilience) is the degree of connectivity enabling or impeding transmission across different parts of a system (such as new pests and diseases or new management techniques). It is important when considering network thresholds.

The controlling variables for the network threshold are connectivity and function. Connectivity is measured in terms of reach (or breadth) and density (or number) of connections. Function is measured in terms of effectiveness and efficiency of flow of information through the network.

Trends

Documented trends significant to the resilience of the industry are as follows:

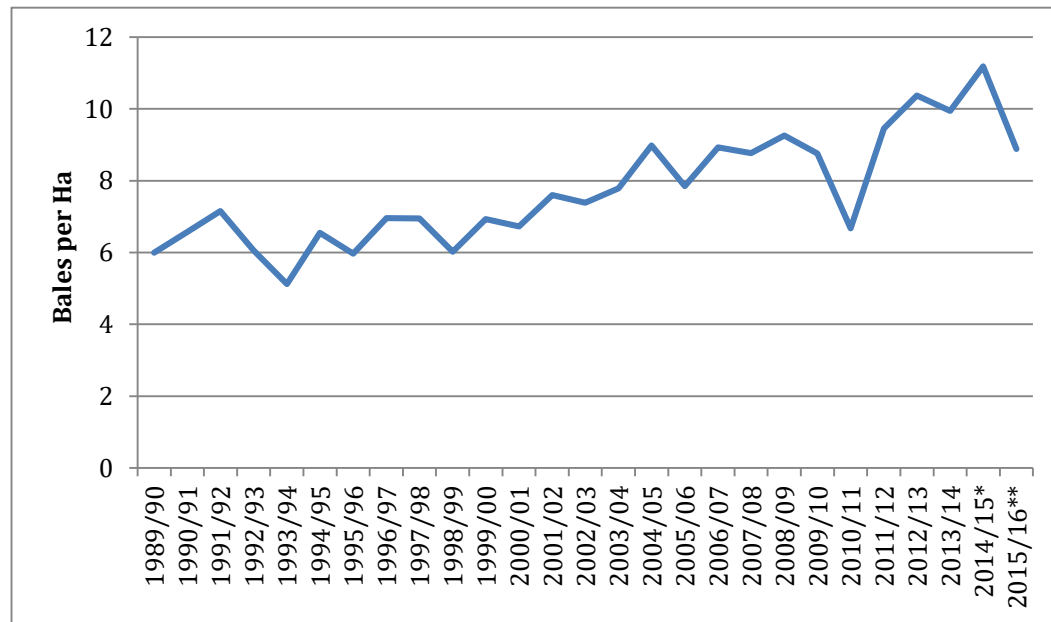
- the natural resource base overall is declining both in terms of condition and scarcity
- demand for fibre globally is increasing, even if cotton's share of it is not
- terms of trade in Australian agriculture are declining
- public investment in research and development infrastructure is declining
- market expectations, particularly around social and environmental issues associated with production, are increasing.

¹⁶ Janssen, M. A., Ö. Bodin, J. M. Anderies, T. Elmqvist, H. Ernstson, R. R. J. McAllister, P. Olsson, and P. Ryan. 2006. Toward a network perspective on the resilience of social-ecological systems. *Ecology and Society* 11(1): 15. [online] URL: <http://www.ecologyandsociety.org/vol11/iss1/art15/>

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Other trends of relevance to the industry scale cotton production system include:

- innovation and increasing use of technology, e.g. the rise of nanotechnology and informatics along with automation, mechanisation and robotics
- new markets, particularly in Asia
- development of alternative artificial fibres
- increasing demand for fibre products overall
- increasing costs and constraints on inputs, including declining resource condition and increasing scarcity
- climate change.
- improving yields per hectare (see Figure 11).



* Estimate based on actual yield/reported crop area **Estimate based on estimated yield/estimated crop area

Figure 11. Australian cotton yield ¹⁷.

States

There are three potential states for the cotton industry as a whole in Australia. These are:

- a broadscale industry
- a niche industry
- no industry.

The niche industry occurs in two ways:

1. Chosen through deliberate transformation (which can be considered a transitional state rather than a state *per se* given there is little change in the dynamics but rather a set of choices made by the industry and rendered possible by research and development, e.g. low input cotton production systems.
2. Imposed through regulation, which relates to a loss of social licence.

¹⁷ Australian cotton yield data from <http://cottonaustralia.com.au/cotton-library/statistics>

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It is generally an inadequate industry response to community concerns and public preferences that pushes the industry towards the regulated niche or no cotton states. Figure 12 illustrates the relationships between these states at the whole-of-industry scale, along with the relevant critical thresholds (research and development investment, network connectivity and function and social licence).

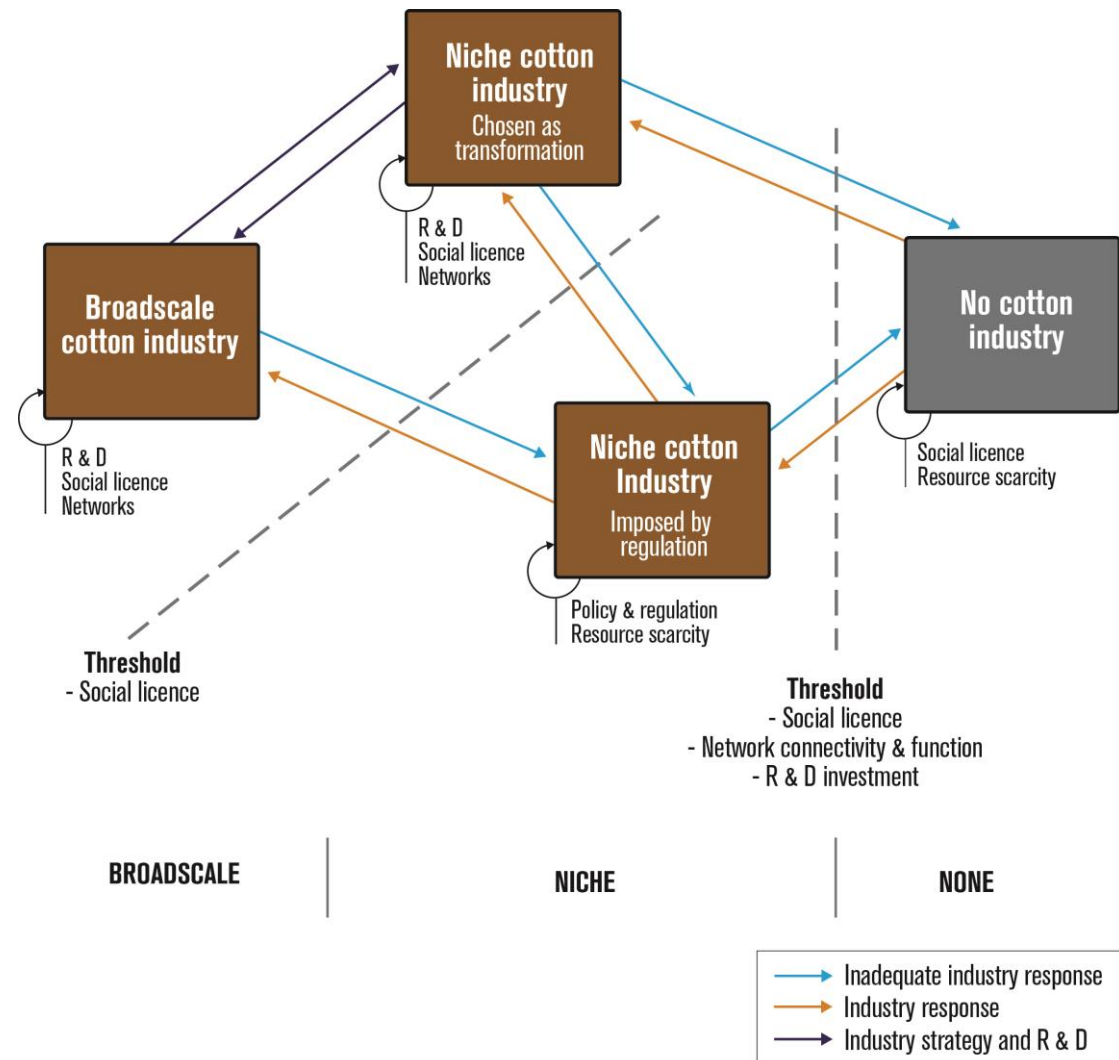


Figure 12. Australian cotton industry states.

Current state

In its current state, cotton production is a broadscale industry occurring between 36° South latitude and 43° North latitude and located in tropical and subtropical regions¹⁸. This means that the potential range for cotton growing covers most of Australia except south and central Victoria and Tasmania. In reality, however, cotton growing is limited to areas of water availability (through irrigation and rainfall) moderated by adequate infrastructure and the degree of pest pressure. In Australia, this currently limits production to NSW (essentially the Murray-Darling Basin) and Queensland (central and southern).

¹⁸ Reller and Gerstenberg, 1997 http://everest.physik.uni-augsburg.de/chemie/forschung/wiss_beitraege/pdf/weisses_gold_wohin.pdf

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At the national scale, Australia has a broadscale cotton industry, although at times such as prolonged drought when production is significantly reduced, the industry may shift towards a “niche” state. Internationally, Australia is a niche producer of high quality cotton.

The industry is striving to achieve a vision of *Differentiated, Responsible, Tough, Successful, Respected and Capable* by 2029¹⁹.

An important question is how much does this vision differ from the industry’s current ‘identity’? Opinions on the identity of the industry are likely to vary depending on scale of interest, who is asked and what priority they give to cotton within their farming enterprise. Perceptions from within the industry will vary considerably from some of those outside the industry.

Desired state

What does a resilient cotton industry look like at a national scale? A resilient cotton industry could potentially occur in either the broadscale or niche states. The visions presented in a number of CRDC reports are helpful starting points in a resilience analysis as they identify what the desired stable state may look like and some of the perceived functions of the industry.

These reports tend to look at the future of the industry at the national level. The *Vision 2029* report, created in 2009-10, draws on perceived aspirations and challenges from across all parts of the industry and supply chain to present the following vision for the industry by 2029²⁰:

“Australian cotton, carefully grown, naturally world’s best”

*“By 2029 the Australian cotton industry will be: **Differentiated** - world leading supplier of an elite quality cotton that is highly sought in premium market segments; **Responsible** - producer and supplier of the most environmentally and socially responsible cotton on the globe; **Tough** - resilient and equipped for future challenges; **Successful** - exciting new levels of performance that transform productivity and profitability of every sector of the industry ; **Respected** - an industry recognised and valued by the wider community for its contribution to fibre and food needs of the world; **Capable** - an industry that retains, attracts and develops highly capable people.”*

The Cotton Futures Forum²¹, held with delegates including researchers, growers, industry personnel, government representatives and CRDC staff and board in 2013, identified that the industry perceives itself as innovative. As part of this, the industry has a culture of attempting to move beyond assumptions and think in new ways. To illustrate this, the delegates’ report from this event outlines research priorities under the three themes of profitable futures, sustainable futures and competitive futures.

¹⁹ Emergent Futures (2010)

²⁰ Emergent Futures (2010)

²¹ Cotton Research and Development and Corporation (2013) *Cotton Futures Forum*. CRDC, Narrabri

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These themes are part of the CRDC's own strategic plan for 2013-18²². Intended outcomes of the plan for farmers and industry, include the following:

*"Cotton is profitable and consistently farmers' crop of choice
The Australian cotton industry is the global leader in sustainable agriculture".*

This raises important challenges in the context of the trends in Australian agriculture generally in relation to sustainability, particularly given the declining natural resource base, expected climate change and declining terms of trade.

²² Cotton Research and Development Corporation (2013) *Strategic R & D Plan 2013 – 2018*. CRDC, Narrabri.

Region scale

The resilience process was applied to each scale to identify elements such as assets, drivers and trends as a way of identifying priorities for how the cotton industry might respond to future challenges. Table 5 is a summary of this process for region scale.

Table 5. The resilience process applied at region scale.

Drivers	Assets	Critical Thresholds	Alternate states	Trends	Inputs	Output
Demand, Climate variability, Climate change, Policy	Regional networks	Connectivity & Function	Producing/ Capable/ Incapable		Energy	Cotton Crop
	Regional expertise			Declining public investment in R&D	Skills & expertise	
	Regional infrastructure	Infrastructure investment		Declining public investment in infrastructure	Labour	
	Native Vegetation	Cover		Declining/variable native vegetation cover		
	Water	Quantity		Declining/stable water availability		
	Land	Quantity				

About the regions

The cotton growing regions of Australia are subject to a wide range of climatic variability both spatially and temporally. Floods, droughts, temperature, rainfall and stored water availability all influence the amount of cotton planted and harvested in each region. How much of the crop is irrigated and how much is grown dryland also varies both between regions and over different years.

Given this variability across the regions, it is challenging to define one specific regional scale. Generally, a cotton growing region is characterised by location in a specific water catchment, availability of processing infrastructure (ginning) and a Cotton Growers Association (i.e. water, infrastructure and networks).

For a more detailed analysis of each of Australia's cotton regions see [Appendix 6](#).

Assets

The key assets that interact at the regional scale are **regional networks, regional expertise and regional infrastructure/technology, native vegetation, water and land** (see Figure 13). Regional expertise is of lesser importance for intervention at this scale given the absence of an associated critical threshold.

Each of the assets is explored in more detail over the page.

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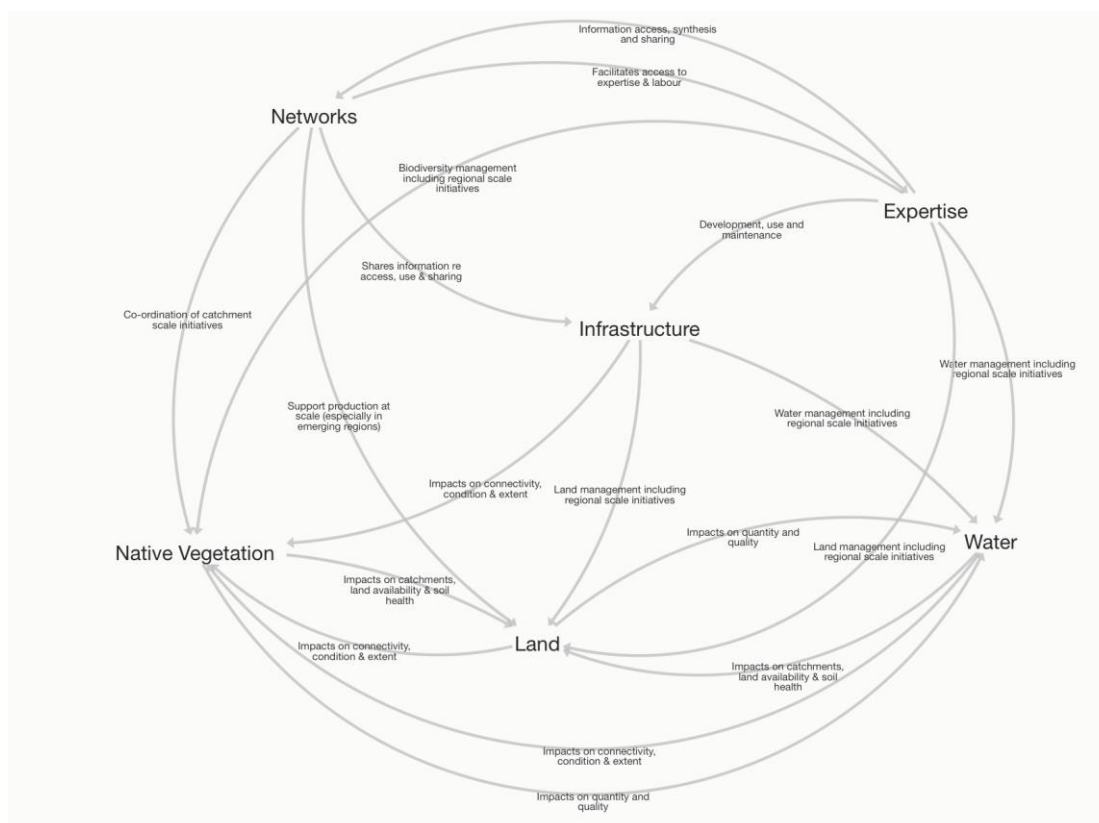


Figure 13. Assets identified for regional scale cotton production.

Regional networks

Regional networks are an important asset at this scale. Connectivity through these networks is a strength as it contributes to the quick uptake of new information and use of infrastructure and technology (particularly important in the emerging cotton regions). This connectedness is expressed in many ways, including sharing of infrastructure as well as expertise, knowledge and skills. This connectedness of farms is also a potential vulnerability as it opens up the possibility of rapid spread of diseases and pests.

Regional networks have fast dynamics, which is important for addressing the ‘tyranny of distance’, and as a way of overcoming the challenges of access to information and decision making as a result of being further from the ‘centre’.

Regional expertise

Expertise is a critical asset at this scale, and it is clear from production statistics and literature about the cotton industry that management is the key to making a difference in terms of profitability. High performing farms have higher yields, but not significantly higher costs. This is because top level management simultaneously controls costs and maximises yield (see [Appendix 7](#) for more details on how skills and expertise impact on profitability).

Regional expertise has fast dynamics and is transferable in that it will follow demand wherever it is.

Expertise is an important asset at the regional scale as individual farms can draw on the regional pool if they have enough capital. Labour availability can be offset by technology, as can skills to a lesser degree, but a minimum level of expertise and labour needs to be

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retained within the region to be able to do so. For more information on grower characteristics (including some data related to levels of expertise), refer to [Appendix 8](#).

Regional infrastructure and technology

Infrastructure, which includes water, cotton processing, communications and the pool for machinery and technology (including contractors), is critical at this scale. There are some regional differences in components of infrastructure, e.g. the relative importance of major irrigation infrastructure and the pool of machinery to share at any one stage in the development of cotton regions.

Regional infrastructure, which individual cotton farms draw on, has moderately slow dynamics and is not transferable.

Native vegetation

Native vegetation plays an important role in maintaining soil and water quality and in supporting populations of beneficial biodiversity²³, hence controlling pest and disease outbreaks which can have an impact on cotton production. It is also important in maintaining the industry's social licence to operate.

Increases in the extent and condition of native vegetation and associated regional landscape connectivity have slow dynamics. Native vegetation decline and associated loss of regional connectivity, such as through land clearing, have much faster dynamics.

Water

This refers to water available for production from a combination of aquifers, rivers and rainfall. Supply sources vary between the regions from regulated and unregulated supply pumped from a river (Namoi and Gwydir valleys, St George), groundwater (Namoi and Gwydir and southern Queensland) and scheme (Coleambally and Emerald).

The drivers of most relevance that affect water are policy driven by community values affecting availability, along with climate variability and climate change, particularly as they affect rainfall.

The dynamics of water availability are slow to moderate, particularly groundwater, although the dynamics for surface water can be faster.

Adding to the issue of availability of water is the capacity to manage annual rainfall or irrigation allocation regionally in any one year as this is limited by rules that are predetermined, usually through regional planning processes and water sharing plans. As well, rainfall is highly variable and is predicted by many climate change scenarios to gradually decrease in the future, particularly for regions in NSW. With regional water storage capacity now relatively fixed this has the potential to decrease water available for irrigation in the long term.

Lobbying through the water allocation planning process is possible but opportunities only arise every decade or less. In the longer term ongoing lobbying through the Murray-Darling Basin planning processes is required to maintain enough allocation to individual regions.

²³ For an example of biodiversity assets and planning within a region with significant cotton production see: Niche Environment and Heritage (2015) *Biodiversity assets of the NWLLS. GIS Landscape Ecology and Species Distribution Modelling*. Report prepared for North West Local Land Services; Ecological (2015) *Development of a Biodiversity Prioritisation Plan for the North West LLS Region*. Report prepared for North West Local Land Services

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On a positive note, evidence suggests water use efficiency is improving, which will probably offset changes in overall water availability and climate change to some degree, but certainly not during a prolonged drought. Water use efficiency has been a priority for the industry in recent years²⁴, but the amount of water used on farm to produce cotton still varies widely, suggesting further scope for water use efficiency measures. See [Appendix 9](#) for more detail on potential water use efficiency gains.

Land

Land available for cotton growing is an asset at the regional scale. Land has slow to moderate dynamics at the regional scale and is affected by climate variability, climate change, policy and demand from other agricultural producers and other industries, particularly as it creates competition for land²⁵.

Competitive land uses, especially mining, CSG and perennial crops replacing cotton, are concerns expressed by growers in the farm/region scale consultation workshops. The threats can be expressed in a number of ways, e.g. competition for labour, land and water along with impacts on social cohesion. In Emerald, for example, there is a fear that planting perennial crops such as macadamias, citrus or grapes could permanently take cotton growing land out of production. In the Namoi, there is concern about the threat of mining and CSG and their potential to disrupt water supply and quality, compete for labour and water, and make some towns less attractive to live in, thereby breaking down supportive social networks and further affecting the availability of skilled labour.

Given the variations from year to year in the area of cotton planted, it is hard to identify or verify any significant trends in land use away from cotton.

Output

The output at the regional scale is a **regional cotton crop**.

For more information on cotton regions in detail and their production levels across Australia refer to [Appendix 6](#).

Inputs

At the regional scale, the inputs applied are **skills and expertise, labour, and energy**.

Technology can offset labour availability requirements (as with the module pickers) but a minimum level of labour will always be required in a region to produce cotton.

²⁴ Australian Cotton Industry Development & Delivery Team (2013) *WATERpak - A guide for irrigation management in cotton and grain farming systems*. Cotton Research and Development Corporation. Narrabri

²⁵ This can also include carbon sequestration land uses such which is being explored in many cotton growing regions. For example: Ecological (2015) *Assessment of Carbon Sequestration Potential for the North West Local Land Services (NWLLS) Region*. Prepared for North West Local Land Services

Drivers

The drivers at the regional scale are **demand, climate change, climate variability** and **policy**.

Demand

Demand for cotton is a critical driver for cotton production at the regional scale as without it there would be no incentive to produce a regional cotton crop. Growers generally switch crops depending on the price likely to be obtained, which is driven in large part by demand for cotton.

Climate change

Climate change is driving the climate system as a whole by shifting seasonal timing, climatic variability and rainfall. It is a slow driver of change, and this has important implications for the expansion or contraction of cotton regions. Refer to previous climate change information (pages 17 and 18) for more details on climate change and its projected impacts in different regions.

Climate variability

At the regional scale, climate variability is operating with fast dynamics and is expressed in major events and natural disasters that can affect an entire valley or catchment in a short period of time. These events are likely to be more common in future in light of climate change drivers outlined above.

Policy

Policy includes regional policy and associated planning for both water and land use. While there is some capacity at a regional level to influence policy debates (advocacy) and associated market mechanisms through collective action, there is more potential to do this at the national industry scale. At the regional scale, overall, policy is an external driver which cannot generally be influenced significantly from within the region alone.

A review of available literature has found that many of the same drivers of change in the cotton industry were identified by interviewees in Prior, Asker and Plant's 2011 study as in the studies mentioned in this report at the national and farm scales. The lesser known drivers highlighted in the study included: the impact of declining cotton production on the movement of skilled labour and decreasing population, as well as quality of life and the sense of community in cotton growing regions.

Drivers and trends at the farm scale, such as weed, pest and diseases²⁶, policy, and seasonal conditions are all likely to have strong flow-on impacts at the regional scale and require regional coordination to manage them.

Internal drivers of change

At the regional scale there are no specific key internal drivers of change, or influencers, identified. This is mostly because the regional scale is variable and challenging to define in clear terms, so in a general sense is affected by drivers operating at the scale above (industry) and the scale below (farm) which flow through (policy and biosecurity).

²⁶ For example: EcoLogical (2015) *Invasive Species Prioritisation and Implementation Framework*. North West Local Land Services. Report prepared for North West Local Land Services

Thresholds

There are five identified critical thresholds at the regional scale as outlined below:

- infrastructure investment
- regional networks (connectivity and function)
- water quantity
- land availability (quantity)
- native vegetation cover.

Infrastructure investment

This threshold occurs where the cost:benefit of replacing infrastructure is positive, particularly water infrastructure and processing infrastructure, i.e. cotton gins. See page 33 for more detail on regional processing infrastructure (ginning).

Who develops and maintains infrastructure is likely to become more problematic in future. An important consideration for the cotton industry (and maybe regional industries more generally) is that it cannot assume that historic levels of public investment in infrastructure, as seen particularly during the establishment of the industry in Australia, will continue in future to the same extent.

An example of this that is particularly relevant to the cotton industry in some regions is that of whether infrastructure for irrigation schemes (e.g. Emerald) will be upgraded as required in future, who will upgrade this infrastructure, who will pay and whether the possibility of stranded assets is seen as an issue to be avoided.

In this context, the viability of a small region would be much more at risk if, for example, five or ten growers permanently left cotton growing. This would have significant flow-on effects for cotton-specific infrastructure such as gins, as well as service providers and regional economies.

There are four alternate states identified which relate to the mix of public and private investment in regional infrastructure, i.e. no investment, private investment, public investment and a mix of public and private investment.

The controlling variable for determining whether or not to replace infrastructure is return on investment. There is no single threshold, as it will differ for public and private investors, however, they are all likely to be greater than 1 in almost all circumstances.

Regional cotton processing infrastructure

Cotton gins are a form of processing infrastructure that is specific to cotton production. Some gins are run by cooperatives while many are run by large cotton marketing and growing companies. Examples of this include:

- Namoi Cotton, which has ten gins producing 1.2 million bales
- Auscott which has five gins
- Queensland Cotton, which has 11 gins producing over 1 million bales.

The capacity of a gin is about 150,000 to 300,000 bales/season. The cost of establishing a new 150,000 bale gin in 2015 was \$24 million (Carrathool)²⁷. Cotton ginning in Australia generates \$3bn revenue, with an annual growth of 23.4% (2010 to 2015) employing 1,471 people and 34 businesses.²⁸

There are identified thresholds around transport to do with distance to gin and costs to get harvested cotton there. This means that at some point it is not financially viable to transport cotton for processing based on the price of cotton and cost of transport and ginning. These factors also have an impact on profitability at the farm scale.

As well as being an important part of the processing chain, cotton gins are important nodes in the growing and marketing system. If there is no gin within an economical transport range of a potential growing area, there can be no cotton farming.

A cotton gin is a significant fixed infrastructure capital expense requiring additional road and electricity upgrades. Paradoxically, to justify building a regional gin, there needs to be enough cotton grown in a region, but many interested growers will not invest in cotton production until a local gin is built. Currently, growers in the Burdekin region are transporting cotton 640 km to Emerald to have it ginned, and this has proved a major barrier to cotton production in the Burdekin.²⁹

Gin operators have demonstrated an ability to run on very low volumes during drought, so it is hard to pinpoint an exact minimum harvest required to keep a gin running. We have assumed that the minimum viable level is around 100,000 to 120,000 bales per season. Based on this:

- an irrigated area with an average yield of 10 bales/ha would require a catchment of 10,000 ha of cotton
- a dryland area, at an estimated 5 bales/ha, would require 20,000 ha of cotton.

Among the main cotton regions only Bourke and Dawson Callide are close to this minimum area of cotton threshold as they have cotton planting areas of around 10,000 ha.

²⁷ Cotton Ginning Market Research Report, ANZSIC A0521, Jan 2015
<http://www.ibisworld.com.au/industry/default.aspx?indid=34>

²⁸ Cotton Ginning Market Research Report, ANZSIC A0521, Jan 2015
<http://www.ibisworld.com.au/industry/default.aspx?indid=34>

²⁹ https://www.google.com.au/webhp?sourceid=chrome-instant&rlz=1C1GGGE_enAU460AU460&ion=1&espv=2&ie=UTF-8#q=cotton+gins+australia&start=10

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Regional networks

Regional networks are important to access essential off-farm infrastructure (hard and soft), supplies, expertise and labour. There is an identified threshold to the level of regional network function.

This threshold is thought to relate to the degree of network function and connectivity at the regional scale. Connectivity is a combination of network reach or breadth of connections and density or number of connections. Refer to the section on network connectivity and function at the industry scale (page 22) for more detail on the importance of network function, potential states and modularity.

There are four potential alternate states identified based on the high or low level of density and reach.

The controlling variables for the regional network threshold are:

- connectivity
- function.

Connectivity is measured in terms of reach (or breadth) and density (or number) of connections. Function is measured in terms of effectiveness and efficiency of flow of information through the network.

Water quantity

There is a threshold for water quantity for production (both groundwater and surface water) in that there is a minimum required to grow a regional crop (see previous page).

Alternate states are as follows:

- adequate water available to produce a regional crop
- inadequate water available so not able to produce a regional crop.

In dryland cotton production systems there may be enough water available initially to start a crop (germination and some growth) but not enough follow-up rain to finish growing the cotton to produce a crop.

The controlling variables on the quantity of water available in a region to grow cotton are:

- policy, based on public preferences as expressed through government policy and planning
- climate change and variability, in particular temperature and rainfall.

Land availability

There is a land availability threshold based on the minimum area of land required to grow a regional crop.

As outlined previously on page 33, if the minimum viable level is around 100,000 to 120,000 bales per season, this would require an area of 10,000 ha (irrigated) or 20,000 ha (dryland) of cotton. While a minimum area of land is required, at this stage there is little evidence of any restriction on land available for growing cotton (either through competition or policy).

In theory government could restrict the area used for cotton growing but that is highly unlikely in the foreseeable future. Dryland cotton may be restricted in future to some extent as a result of climate change. Competition for inputs such as water could reduce the

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total area used for cotton under certain price conditions but this would not be due to a reduction in land availability by itself.

Alternate states are as follows:

- adequate area, i.e. capable of producing a regional crop
- inadequate area so not capable of growing a regional crop.

The controlling variables for land availability are as follows:

- land use value for alternative uses (such as mining)
- social licence (public preferences).

Native vegetation

There are regional thresholds regarding native vegetation cover to support diversity of species and functioning ecosystems. There are three thresholds identified for 10, 30 and 70% of native vegetation cover retained.

There are marked changes in the rate of biodiversity loss as the extent of cover is reduced (see Figure 14) but there are usually time lags before it occurs (see Figure 15). The most important of these is the 30% native vegetation threshold.

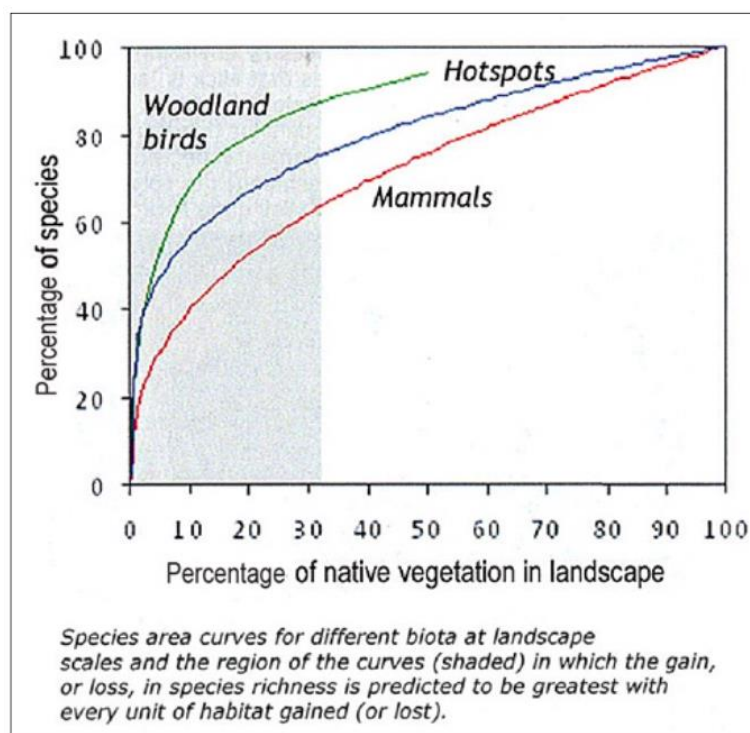


Figure 14. Species area curves ³⁰.

³⁰ Gibbons, P. 2009. Where would you put your conservation dollar? *Decision Point*, 30, 8-9

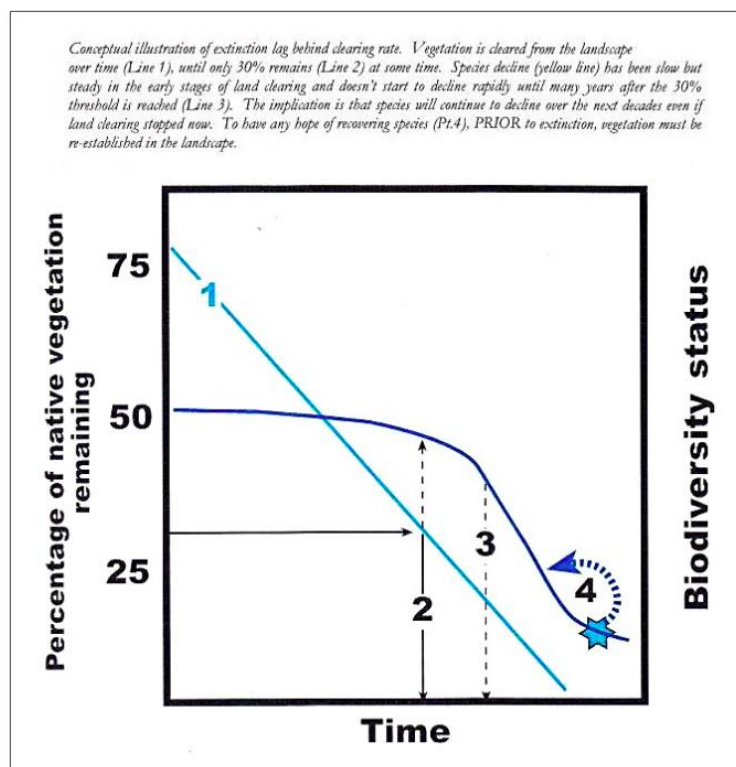


Figure 15. Conceptual model of extinction lag time ³¹.

The connection between native vegetation and productivity is complex and affects biodiversity, microclimate, land and water. There are benefits, such as pest control, and costs, such as reduced area for crops. Overall it is thought that retaining biodiversity in the landscape is likely to buffer best against future shocks, climate change and variability. Many cotton regions have already crossed at least one of these thresholds.

Alternate states are as follows:

- declining
- stable
- increasing.

The controlling variable for native vegetation is cover.

Trends

The declining availability of natural resources, which is documented for most cotton growing regions, is an important trend, i.e. native vegetation cover is declining in most regions including cotton growing regions³².

³¹ James, C. D. & Saunders, D. A., 2001. *A framework for terrestrial biodiversity targets in the Murray-Darling Basin*. Sustainable Ecosystems and Murray-Darling Basin Commission, Canberra

³² NWLLS region for example: Ecological (2014) *Construction of a Vegetation Map for the North West Local Land Services Region*. Extant and Pre-European Distribution of Regional Vegetation Communities. Prepared for North West Local Land Services

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Overall, public investment in regional infrastructure is declining across most of the major cotton growing regions. This is part of the broader national trend away from public investment to a user pays model.

While it is often cited as a concern by cotton growers in the regions, given the variations from year to year in the area of cotton planted, it is hard to identify or verify any significant trends in land use away from cotton.

States

There are three alternate states for cotton regions based on production (see Figure 16). These are:

- producing - a regional crop is produced
- capable of production - a regional crop is not produced even though there is the option, e.g. if growing a different crop is more profitable
- incapable - a regional cotton crop cannot be produced.

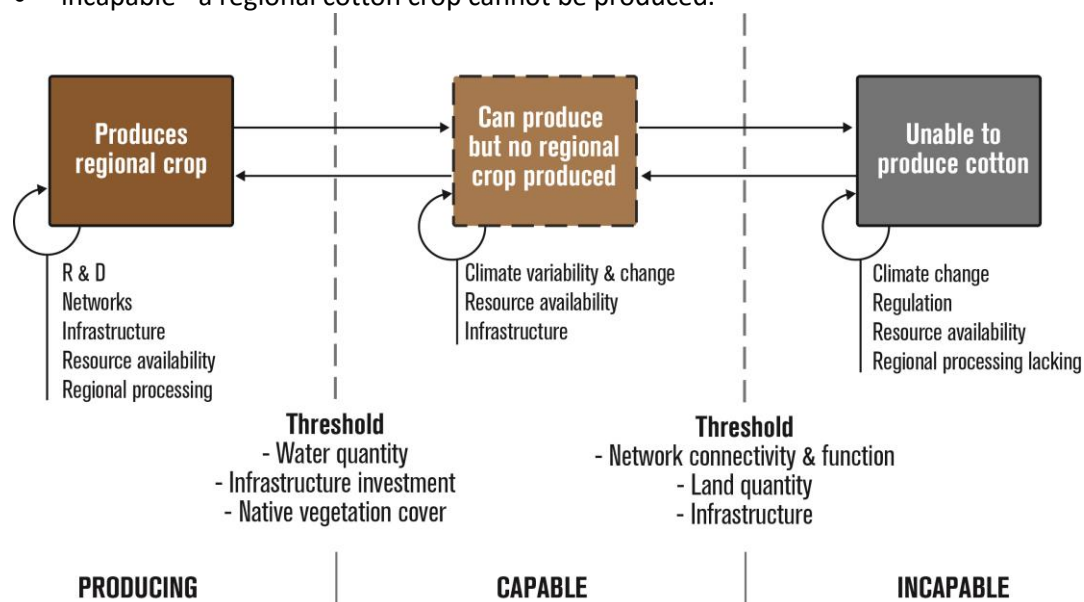


Figure 16. Alternate states for cotton regions.

Current state

A regional view focusing on the cotton-producing valleys in Queensland and NSW has received less attention in the CRDC's work compared to national and farm scale, although studies of on-farm behaviour and performance such as the *Australian Cotton Comparative Analysis* do collate some data by valley, with some differences acknowledged. Work by the previous Cotton Catchment Communities CRC focused more on the regional scale.

Research examining possible regions for expansion³³ suggests options are limited, although research at smaller scales may find exceptions to this general conclusion. This is against a background where the area where cotton is grown has expanded significantly in the recent past, with the industry estimating that 75% of 2010-11 growers were growing their first

³³ Ecological Australia (2014) *Potential for Growth in the Australian Cotton Industry. Volume 1: Research and Findings*. Prepared for the Cotton Research and Development Corporation

cotton crop³⁴. An example is the Ord, where cotton was grown in the 1960s but ceased as a result of insect problems. In future it is likely to be an important growing area again as a result of GM varieties, which are resistant to some significant pests³⁵.

Desired state

*Australian Cotton Futures: Building Capacity for Resilient & Adaptive Communities*³⁶ was commissioned to explore the compatibility of the cotton community's perspectives about their desired futures and their alignment with the *Vision 2029*³⁷ process occurring from the industry perspective at a similar time. The report draws on interviews with individuals in communities where the economy either has been, or continues to be, underpinned by cotton production.

Another community visioning project occurred in one case study community in Queensland. This case study asked participants, including community members who were not part of the cotton industry, to talk about ideas of a 'healthy functioning community' (which we could also describe as a resilient community).

In both parts of the process, the importance of the cotton industry was acknowledged. Its economic contribution as the most profitable and favoured agricultural crop in the communities was valued, as well as its role in bringing new people to the region. Its ability to contribute to the services and the whole quality of life in the communities, including healthcare and sports teams, was recognised.

In the consultations as part of the case study, participants acknowledged the importance of diversifying the economy into areas such as tourism and mining. Growing crops other than cotton was perceived as valuable for flexibility and survival of cotton producers and human capital in low water years.

A healthy functioning community, as perceived by the cotton communities in the Balonne Shire of south-western Queensland, required more than a strong profit from cotton, although this was a positive contributing factor. Other issues, such as quality education in a community and allowing school students and their parents to stay in the community throughout their children's education, for example, were other valued aspects of the community. People and sense of community were important, and this explains some concerns about mechanisation of the cotton industry reducing labour needs. The report concludes that:

*"Given the adaptability and flexibility of cotton farmers in this study, particularly in relation to water uncertainty, it's likely that for the members of the 'cotton communities' included in this research, that cotton is a means to an end, and that while the communities may change gradually without cotton, they would still remain largely agricultural."*³⁸

³⁴ Inovact Consulting (2012) *Australian Cotton Industry: Third Environmental Assessment*. Report prepared for Cotton Research and Development Corporation. p 24

³⁵ Inovact Consulting (2012)

³⁶ Prior T., Asker, S. and Plant, R. (2011) *Australian Cotton Futures: Final Forum Report*. Institute for Sustainable Futures, University of Technology, Sydney: for the Cotton Catchment Communities CRC, December 2011

³⁷ Emergent Futures (2010)

³⁸ Prior T., Asker, S. and Plant, R. op. cit., p. 24

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Climate (particularly temperature and rainfall) is an important factor. These results are in line with previous studies looking at community wellbeing and adaptability in cotton regions³⁹. This is relevant both for regions and the industry as a whole.

³⁹ Instinct and Reason (2012). *Adaptive Capacity and Sustainable Communities – Main Study*. Report prepared for The Australian National University.

Farm scale

The resilience process was applied to each scale to identify elements such as assets, drivers and trends as a way of identifying priorities for how the cotton industry might respond to future challenges. Table 6 is a summary of this process for farm scale.

Table 6. The resilience process applied at farm scale.

Drivers	Assets	Critical Thresholds	Alternate states	Trends	Inputs	Internal "driver" Influencer	Output
Price, Climate variability, Policy	Water (ground and surface)	Quantity & Quality	Producing/ Capable/ Incapable	Declining/stable water quality	Fertiliser	Biosecurity	Cotton Crop
	Soil	Health		Declining/variable water availability	Herbicide		
	Capital	Profitability		Declining/stable soil health	Skills & expertise		
	Habitat	Proximity		Increasing input costs	Seed		
	Energy			Increasing habitat fragmentation	Pesticide		
	Infrastructure			Increasing cotton yield	Beneficial biodiversity		
				Increasing energy costs	Off/other farm income		
					Technology inc. GM		
					Labour		

Assets

The important assets that interact at the farm scale are **water, soil health, capital, energy, infrastructure** and **habitat** (see Figure 17). Water, soil, capital and habitat all have associated thresholds.

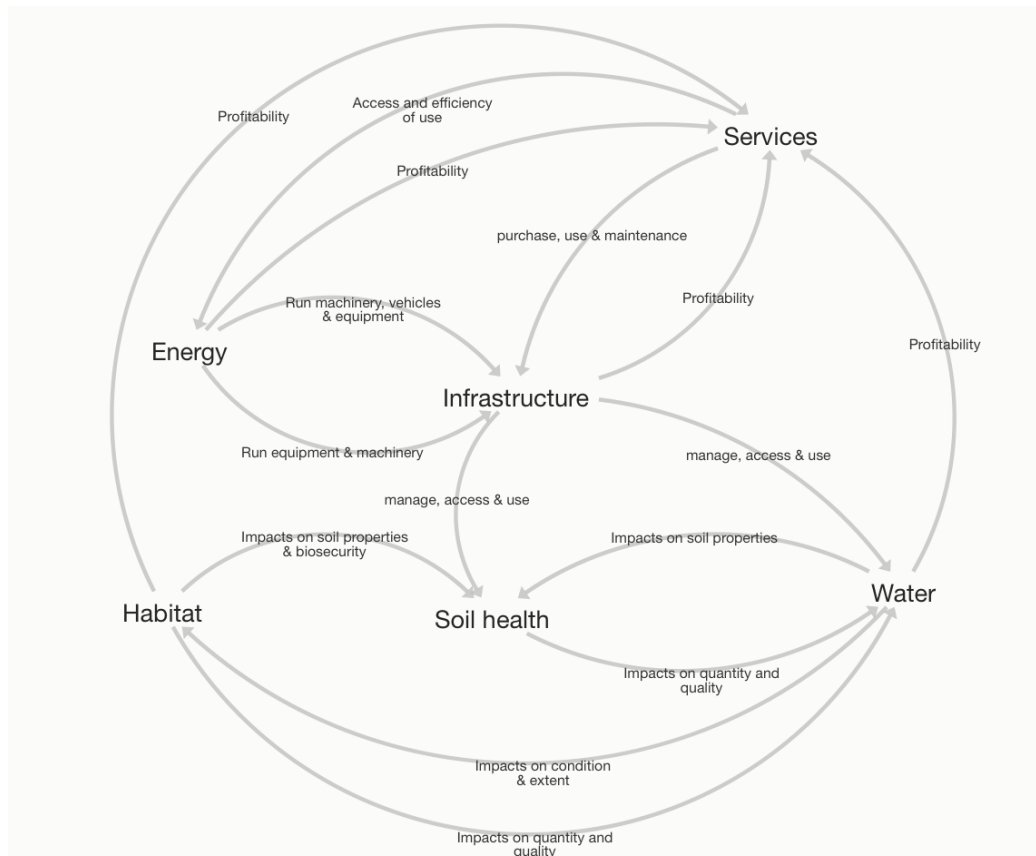


Figure 17. Assets identified for farm scale.

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Water

Water sources comprise groundwater and surface water. Availability and quality vary, with climate (both variability and change) being a key driver affecting this asset. The water source impacts on the cost and reliability of supply under different dynamics e.g. groundwater can be a more reliable source but costs more to access.

As cotton is an annual crop, growers are able to make decisions each season on whether to grow it and how much relative to other crops. This decision is influenced by relative commodity prices, input costs, particularly the cost of water, and seasonal factors. This explains the decline in production seen from the late 1990s to the late 2000s, which reflected declining water availability in major cotton-producing areas⁴⁰.

This flexibility at the property scale is a major source of resilience for farm businesses, although the elasticity impacts heavily on businesses beyond the farm gate at regional and industry scales.

Soil health

This includes biophysical, chemical and physical properties. The functions provided by healthy soils include nutrient cycling, structure, water holding capacity, permeability and provision of organic matter. Groundcover plays an important role in soil health but is highly variable under cropping land use⁴¹.

Salinity, sodicity and decline of structure are all identified as the key soil health issues for cotton growing at farm scale⁴².

Capital

Capital brings the capacity to access energy, infrastructure and expertise, i.e. other assets and inputs, as long as they are available from within the surrounding region.

Other farm income also plays a role, with most cotton being grown as part of mixed farming enterprises. Most cotton growers derive at least half of their farm income from cotton. For more information on the percentage of farm income derived from cotton by region, along with the nature of and trends in relation to farm ownership (family or corporate) refer to [Appendix 10](#).

Comparative gross margins show that cotton is a highly profitable crop under many scenarios. For more information on historical gross margins comparing cotton with alternative crops refer to [Appendix 11](#).

Energy

At the farm scale energy is an asset. It is an important cost component of the profitability threshold (see page 46). Energy is not included as an input at this level although it is at regional scale.

⁴⁰ http://archive.nwc.gov.au/_data/assets/pdf_file/0011/19883/Industry-case-study_Cotton.pdf

⁴¹ Danaher, T., Horn, G., Burley, H., Higgins, D. and Sparke, G. (2012) *Namoi Catchment Ground Cover Assessment – Determining Groundcover at the Catchment and Sub-catchment Scale*. Report prepared for Namoi Catchment Management Authority

⁴² Cotton Info Team (2015), *Australian Cotton Production Manual*. Cotton Info Team. pp. 45-46

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The cotton industry relies heavily on energy for cotton production, e.g. diesel for machinery and diesel and electricity for pumping⁴³. Energy is identified by the cotton industry as one of the fastest growing input costs and this trend is predicted to continue⁴⁴. This was confirmed in the farm/region consultation workshops with growers commenting that energy costs are rising steeply and are becoming a significant item in the budget, especially when combined with the cost of water (one of the top three or four costs of growing cotton).

At present, most energy is from conventional sources. Diesel fuel provides at least 90% of the direct energy used on irrigated cotton farms⁴⁵. Tractor operations are also a significant component of direct energy use⁴⁶. Given the industry's reliance on energy, renewable energy sources could be important in future. With cotton often being grown in a mixed farming setting, there are some interesting possibilities regarding use of waste biomass for energy generation.

Infrastructure

Farm scale infrastructure is an asset. The purchase and maintenance of infrastructure is a cost component that affects capital, which is another important asset at the farm scale.

Habitat

On-farm habitat is an asset and plays an important role in supporting beneficials such as microbiota, invertebrates, bats and birds. It includes local landscape connectivity and riparian vegetation buffers. Habitat has an impact on the cost of farming by reducing pest control requirements, although this is less significant than the impacts of soil health and water availability.

Output

The output at the farm scale is a **cotton crop**.

The average crop size per farm has varied widely, but was between 200 and 300 ha through the 2000s (see Figure 18). Caution is needed in interpreting the averages as the presence of very large corporate cotton producing enterprises skews the means. While it is hard to confirm the distribution of farm sizes it should be noted that four of the larger cotton growing enterprises (Cubbie, Eastern Australia Agriculture Kia Ora and Clyde properties, Auscott and Darling Farms) have the potential to supply about 16% of the Australian crop (calculated on available reported irrigated area and average Australian yield).

Most cotton-producing farms are mixed enterprises of irrigation and dryland grain production systems and cattle. Cotton is usually the main irrigated crop in these farms and it is often grown opportunistically, hence the variation in the number of 'cotton farms' over the last 25 years.

⁴³ Chen, G. and Baillie, C. (2007) *Development of Energy/Calc – A Tool to Assess Cotton On-Farm Energy Uses*. National Centre for Engineering in Agricultural Production 1002565/1, USQ, Toowoomba

⁴⁴ Cotton Info Team 2015. p. 48

⁴⁵ Foley, J.P., Sandell, G. R., Szabo, P. M., Scobie, M. and Baillie, C. P. (2015). *Improving energy efficiency on irrigated Australian cotton farms. Benchmarking report*. NCEA Publication 1005371/1. p. 6

⁴⁶ Foley, (2015) *et al.* p 7

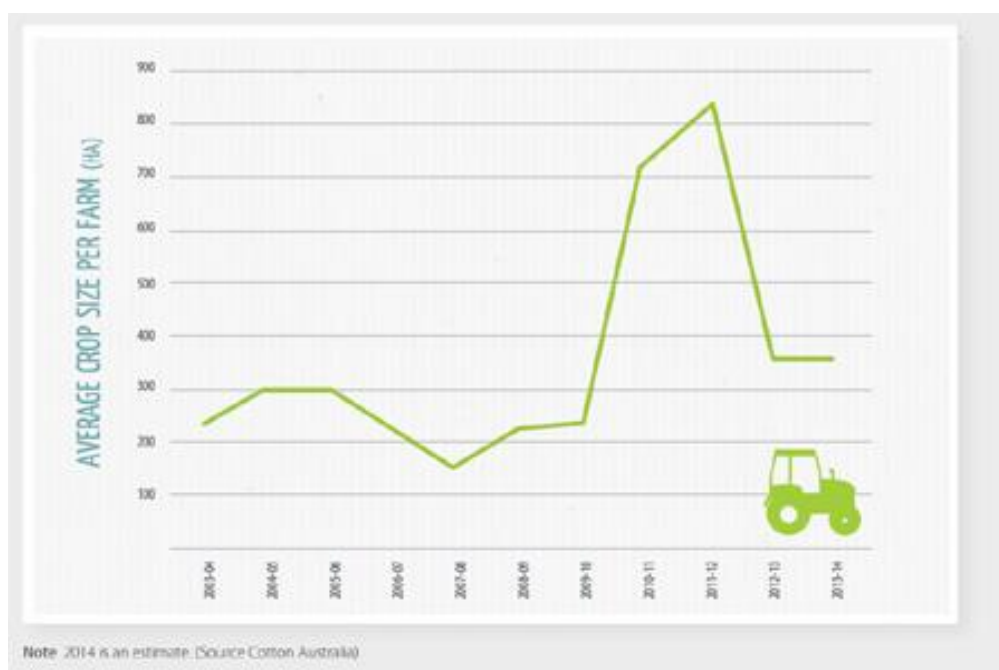


Figure 18. The average cotton crop size per farm 2003-14.

Inputs

At the farm scale, the inputs applied are **fertiliser, herbicide, pesticide, seed, skills and expertise** (including research and development on farm and external, and MyBMP⁴⁷), **beneficial biodiversity, technology** (including GM), **labour** and **off/other farm income**.

Skills and expertise is an input on farm. While management skills, familiarity and association with the specific farm is important for on-farm decision making, management expertise is considered an input rather than an asset at the farm scale. This is because skills and expertise can be drawn on from the surrounding regional scale using capital to best apply the right set of other inputs (including labour, chemicals and training) to generate a crop and produce cotton.

Technology developments of interest to the cotton industry include GM, informatics, nanotechnology, mechanisation and robotics. A general issue expressed by growers and others at the farm/region scale workshops is whether they are heading down a technology trap as a result of their ever-increasing reliance on technological advances to stay ahead of costs and maximise yield and production. This could be decreasing options rather than increasing them and making growers vulnerable because they are relying on things outside of their control, e.g. software services in the cloud and cotton varieties with resistance built in to one particular herbicide. This has implications for general resilience discussed later in

⁴⁷ myBMP is the Australian cotton industry's voluntary farm and environmental management system for growers to improve on-farm production. myBMP ensures that the Australian cotton industry produces economically, socially and environmentally sustainable cotton. Forty-five per cent of Australia's cotton produced is grown on farms participating in the myBMP program. (Note, however, the possibility of this to be mainly one sector of the cotton industry e.g. large corporate farms.)

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this report. The main elements of this potential technology trap are briefly outlined below to highlight the ways in which this may be reducing options for cotton growers.

Herbicide is an important input. Glyphosate resistance is becoming a significant issue for cotton growers and agriculture generally because most weed control relies on it, and there aren't any equivalent replacement options currently available.

As identified by farm/region workshop participants, while there are around 20 different varieties of cotton seed available, most of the industry relies on one or two, which are higher yielding and produce higher quality fibre.

With no real growth in the value of Australian cotton in the world market over the past 15 years, increasing input costs are outweighing the value created by improvements in yield. In this environment, the challenge for the future profitability of Australia's cotton farmers is twofold. Firstly, protecting their crops from attacks by insect pests, weeds and diseases and, secondly, optimising the use of inputs such as water, energy and fertiliser to maximise yields and improve cost efficiencies.⁴⁸ For more information on input cost trends, refer to [Appendix 12](#).

Drivers

At the farm scale, the key drivers of change on the system are **price, climate variability and policy**.

Price

Global economic dynamics are the main influence on price, and they are well beyond the scale that an individual grower or the industry can influence. Factors that affect the market for cotton include the state of the world economy, agricultural politics, fashion trends, synthetic fibre price, weather, natural disasters and the prevailing conditions of supply and demand.

As a result, individual businesses are price takers; they cannot control cotton price, only some limited factors that marginally influence it, e.g. variety, timing of sale and market destination. In this context, it is stated that 'Australia's growers produce very high quality cotton with low contamination that is in demand on the world market and commands a premium price'⁴⁹.

Importantly, many farmers who grow cotton consider themselves farmers first and cotton growers second, and consider their planting options each year depending on the current context and conditions. Price is critical in deciding whether or not to plant cotton.

At the farm scale, price as a driver has both fast and slow dynamics. Its fast dynamics are related to its regular fluctuations, i.e. day/month/season/year to year; its slow dynamics are based on the overall trend in price. Price can also act as a shock if there is a significant spike or sudden drop.

⁴⁸ <http://www.crdc.com.au/research-development?q=/node/91>

⁴⁹ <http://cottonaustralia.com.au/cotton-library/fact-sheets/cotton-fact-file-the-economics-of-cotton-in-australia>

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Market conditions also influence the area planted to cotton, e.g. the reduction in cotton production during 2008 was exacerbated by relatively high wheat prices, which resulted in irrigators switching crops.⁵⁰

Individual farm businesses can only influence parts of this equation, hence their location in relation to the profitability threshold. The focus on yield per hectare, rather than price per bale, is an appropriate measure of viability and business sustainability so long as yield increase can offset declining terms of trade.

To effectively manage for this driver, the focus must be on productivity and profitability, as outlined in the profitability threshold, rather than production, which is also a challenge for Australian agriculture more broadly. This requires high levels of strategic decision-making and operational skills, which can be acquired over a long timeframe through experience and trial and error or through training and good support services in the short term.

By focussing on the net return per bale, a range of transformative options can be considered, including lower input/lower output but higher profit cotton production strategies.

For more information on the determinants of price for cotton, refer to [Appendix 13](#).

Climate variability

At the farm scale, climate variability is the driver. Unlike industry and regional scales, the farm scale has fast dynamics, but not as fast as price. Rainfall and temperature are the critical factors for climate variability at the local scale.

Policy

At the farm scale, policy has moderate to slow dynamics in that it doesn't change 'overnight', rather there are stages of development operating at the other scales that feed back through to the farm scale. This results in a lead-time and slower dynamic to the system function of this driver.

For more information on drivers of change at the farm scale identified in the literature review refer to [Appendix 14](#).

Internal drivers of change

Internal drivers of change at the farm scale are **pests**, **weeds** and **diseases**. These are summarised using the term 'biosecurity' in this report.

Thresholds

Five thresholds were identified at the farm scale, as follows:

- profitability
- water quantity
- water quality
- soil health
- habitat proximity.

⁵⁰ http://archive.nwc.gov.au/_data/assets/pdf_file/0011/19883/Industry-case-study_Cotton.pdf

Profitability

Expectations of profitability are a key component of the decision to plant cotton or not, especially for the large number of smaller mixed farms, which tend to move in and out of cotton.

Farm operating profit (income less operating expenses, including owner wages or equivalent) is the headline figure, but a grower's financial flexibility is better measured by deducting interest payments on farm business loans, i.e. farm net profit. A more accurate indicator of farm liquidity is when farm debt and debt servicing requirements are measured against income.

From a resilience perspective, the profitability threshold is based on farm financial liquidity (farm net profit or debt:income ratio). This influences the extent to which a farm can service its debts and retain access to additional capital should this be required to respond to a shock. The profitability threshold is where the debt:income ratio is too low for too long, e.g. as with foreclosures.

There is also a related issue of seasonal profitability (profit per hectare), which will influence the decision of how much cotton to plant and is on a much shorter timeframe. This threshold is nested within the critical debt:income profitability threshold, but is important given its impact on farm scale decision making.

There are three states of farm scale profitability, as follows:

1. Where there is insufficient farm net profit, so there is not enough seasonal profit to invest in maintaining capital and buffering against future shocks.
2. Where the farm is profitable enough to be able to maintain critical assets, buy inputs and service debt.
3. Where there is excess profit providing scope to build capital, build diversity, spread risk and create buffers.

Profitability at the farm scale is linked to research and development capacity at the whole-of-industry scale (see Figure 3, page 9). It is also strongly influenced by productivity.

The controlling variable for profitability is the debt:income ratio.

Water quality and quantity

Water has both quantity and quality thresholds at the farm scale.

Quantity

The threshold for water quantity (groundwater and surface water) is whether or not there is enough to grow a cotton crop. This is determined by the amount of water required to grow a crop where yield will be profitable, i.e. the amount of water needed is more than just the biophysical minimum requirement for plant growth. This amount will be different for dryland (rain fed) and irrigated crops. For irrigated crops, another factor is high and low security of irrigation water.

This means that the nature of the risks changes depending on whether the cotton production system is irrigated or dryland. In turn, these change the way the system dynamics operate - both the source of the asset and the rate of fluctuation due to climate and policy drivers in particular.

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For **groundwater quantity**, the controlling variables are groundwater recharge (governed by rainfall and land use) and extraction rate. For **surface water quantity**, the controlling variable is rainfall.

The alternate states (as outlined in Figure 19) are:

- enough water to grow a cotton crop to produce maximum yield
- Insufficient water to produce maximum yield
- insufficient water to grow a cotton crop.

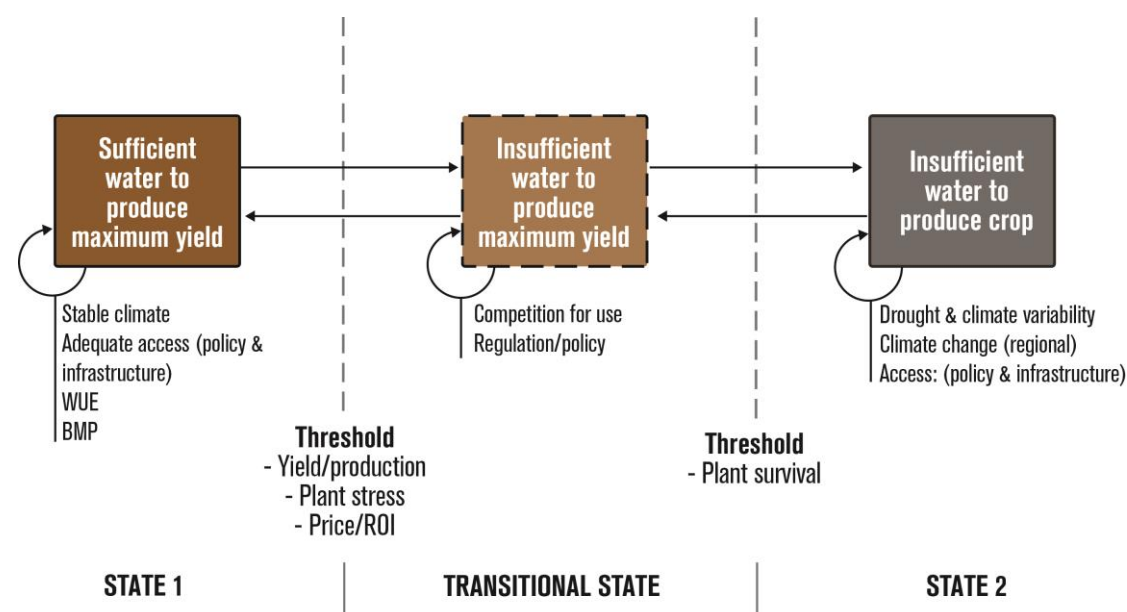


Figure 19. Water quantity states on farm.

There is an important feedback loop around extended drought or climate shift leading to reduced investment in infrastructure and policy restrictions on access to water, with knock-on effects on water availability.

The moisture level at wilt point for a cotton plant threshold is one of a series of nested water thresholds. This is mainly an issue for dryland cotton. Farm management and technology to maximise water use efficiency can ensure this moisture/plant wilt threshold is managed effectively, however, climate variability and its impact on drought and water availability and heat waves will have potential impact in any one season.

Capacity is limited to manage annual rainfall or irrigation allocation so that there is enough water to grow a viable area of cotton in any year. The main reasons for this are that the annual allocation for irrigation is based on predetermined rules, rainfall is highly variable and water storage capacity on and off farm is now relatively fixed.

Quality

There are two nested thresholds for water quality. One relates to the biophysical minimum for plant growth; the other is the point at which a viable crop is produced so water quality is adequate to produce cotton (see Figure 20). This is determined by the amount of water required to grow a crop where plant growth and yield will be profitable, i.e. the quality of water needed is more than the biophysical minimum requirement for plant growth (as for water quantity).

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The water quality thresholds which determine which crop can be grown are well understood. By the time this threshold is reached, the other threshold relating to water quality adequate for yield above the biophysical minimum requirement has already been crossed (most likely along with other thresholds such as profitability).

Quality relates particularly to pH and salinity in the cotton industry. For pH, there are a range of thresholds⁵¹ of particular relevance for irrigation water as outlined in Table 7.

Table 7. pH thresholds for crops.

pH	Quality issues
<4	irrigation water can contribute to soil acidity
5.5-8.8	suitable for most plants
>9	irrigation water may contribute to alkalinity

Salinity thresholds are well understood for a range of crops and pasture types. Table 8 lists salinity thresholds⁵² for cotton crops depending on soil type, and their impact on yield.

Table 8. Salinity thresholds for cotton crops.

Tolerance of cotton to water salinity and root zone salinity						
Soil type	Well drained soils		Moderate to slow draining soils		Very slow draining soils	
Yield reduction	Up to 10%	25%	Up to 10%	25%	Up to 10%	25%
Water salinity limits for surface irrigation (in dS/m)	7.7	12.5	5.1	8.3	2.5	4.2

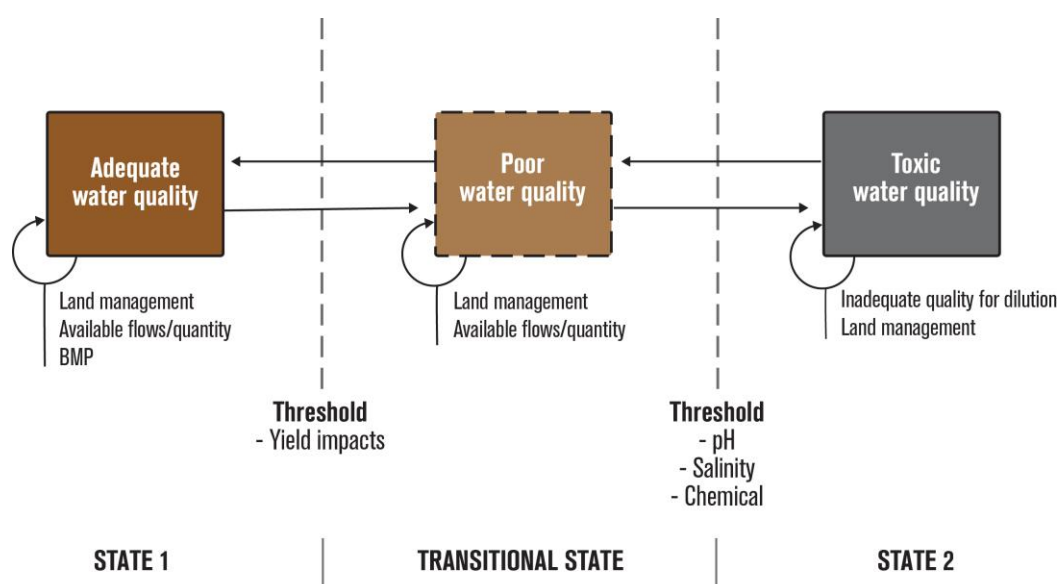


Figure 20. Water quality states on farm.

⁵¹ Cotton Info Team (2015) *Australian Cotton Production Manual 2015*. Cotton Info Team. p. 83

⁵² Cotton Info Team (2015) *Ibid*

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The alternate states are as follows:

- adequate
- poor (a transitional state)
- toxic.

The controlling variable for water quality is total volume. For surface water this is measured as flow (in terms of in-stream and inflows into catchments). For groundwater this is measured as access to volume of high quality water for dilution.

Soil health

How soil health affects plant growth is based on biological, physical and chemical attributes. As with water quantity and quality, there are two nested thresholds associated with soil health.

The first threshold is the point at which a plant cannot be grown in the soil, e.g. structural decline is extreme and cannot support plant growth. Farmers are a long way from this threshold in most Australian cotton soils, but it exists for every soil type.

The second threshold relates to crop yield, i.e. the point at which even if you get a crop the yield is so low that it is not worth it. In this case the decision would be not to plant as a viable crop could not be grown.

It is acknowledged by many in the Australian cotton industry, both through consultation and in the reviewed literature⁵³, that the soil is being 'mined' and production levels are well beyond the natural capacity of the soil. To maintain production requires inputs such as fertilisers.

Table 9 lists the four categories of soil health⁵⁴ referred to in current cotton industry literature based on soil sodicity in particular.

Table 9. Sodicity classification for Australian soils.

Classification	Definition
Non sodic	ESP < 6
Low sodic	ESP 6 to 10
Moderately sodic	ESP 10 to 15
Highly sodic	ESP > 15

The alternate states are healthy or poor.

The controlling variable for soil health is soil carbon.

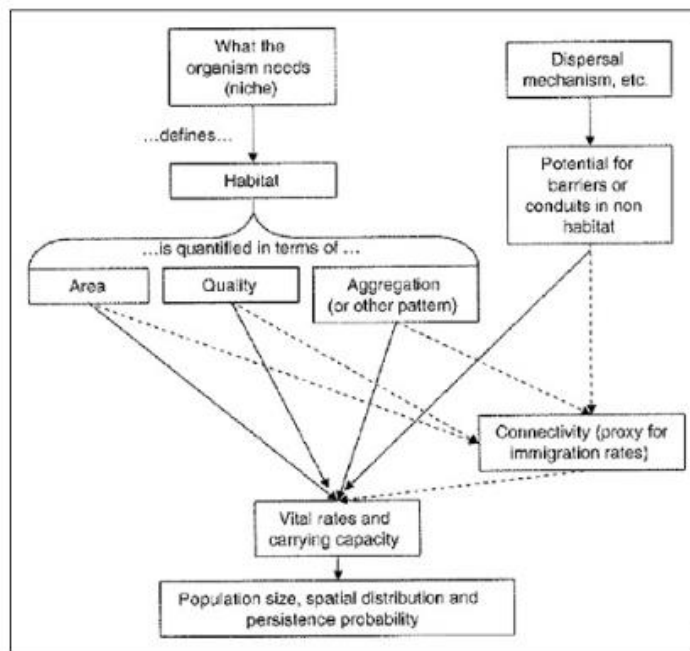
⁵³ Issue identified by growers and service providers at all three farm/region workshops, and the industry workshop held in 2015

⁵⁴ Cotton Info Team (2015). p. 45

Habitat proximity

Habitat at the farm scale makes a significant contribution to pest control and social licence. It has a weaker threshold effect than the other critical thresholds at the farm scale, and can be considered a nested threshold under the farm scale profitability threshold.

Localised habitat value is related largely to proximity⁵⁵; diversity⁵⁶ and extent (also expressed as pattern, quality and area as in Figure 21).



Source: Hodgson et al (2009)

Figure 21. Conceptual model of role of habitat in population persistence ⁵⁷.

There is an important (and related) threshold for proximity of native vegetation (within 500 m of native vegetation⁵⁸) to gain the benefits of beneficial biodiversity. This is related to the native vegetation cover thresholds at the regional scale (both private and public land⁵⁹).

Alternate states for habitat proximity on farm are as follows:

- declining
- stable
- increasing.

⁵⁵ Bianchi, F.J.J.A., Walters, B. J., ten Hove, A. L. T., Cunningham, S. A., van der Werf, W., Douma, J. C., and Schellhorn, N. A. (2015) Early-season crop colonization by parasitoids is associated with native vegetation, but is spatially and temporally erratic. *Agriculture, Ecosystems and Environment*, 207: 10-16

⁵⁶ Schellhorn, N. A. (n.d.) *Pest suppressive landscapes: Understanding Habitat Function*. CSIRO

⁵⁷ Hodgson J. A., Thomas, C. D., Wintle, B. A., and Moilanen, A. (2009). Climate Change, connectivity and conservation decision making: back to basics. *Journal of Applied Ecology*, 46: 964-969

⁵⁸ Bianchi, et al. (2015)

⁵⁹ Habitat proximity can range across tenures. Travelling Stock Routes for example can provide important habitat in cotton regions which has flow on effects on farm. For example, see: Ecosure (2015) *Ecological Values and Condition of the Travelling Stock Routes in the North West Local Land Services Region*. Report prepared for North West Local Land Services

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The controlling variables for habitat proximity at the farm scale are:

- patch size
- configuration.

Trends

An important trend is the ongoing cost/price squeeze, components of which include increasing costs of technology and input costs such as energy.

As outlined in the previous section, input costs are increasing and outweighing the value created by improvements in yield. For more information on input cost trends, refer to [Appendix 12](#).

Declining resource availability, which has been identified in cotton industry literature, is an ongoing trend⁶⁰. It includes declining water availability, greater variability in rainfall, declining soil health and variable/declining habitat cover and diversity. A resource of particular importance is water, the availability of which is being affected by both policy and climate change.

In terms of profitability, the threat to the high cost/high technology model is increasing technology costs, e.g. the steady increase in the Bollgard licence fee (up over 170% since 2004 on a rolling 3-year average) and increasing seed (up 42%) and fertiliser costs (up 68%) over the same period. On the flipside, insecticide costs have fallen (down 72%), chipping costs have fallen (down 95%) and electricity, fuel and oil costs vary⁶¹.

For more information on farm scale trends identified in the literature review, refer to [Appendix 15](#).

States

Current state

There are three alternate states for the cotton farm as follows (see Figure 22):

- producing - producing cotton
- capable - able but not currently producing cotton
- incapable - unable to produce cotton.

⁶⁰ Namoi CMA (2013) *Namoi Catchment Management Plan 2013 Update* and supplementary documents. Namoi Catchment Management Authority, Gunnedah
NSW Environment and Protection Authority (EPA) (2012) *NSW State of the Environment Report 2012*. EPA <https://www.epa.nsw.gov.au/soe/>
State of the Environment 2011 Committee (2011). *Australia state of the environment 2011*. Canberra, DSEWPac

⁶¹ Boyce 2012

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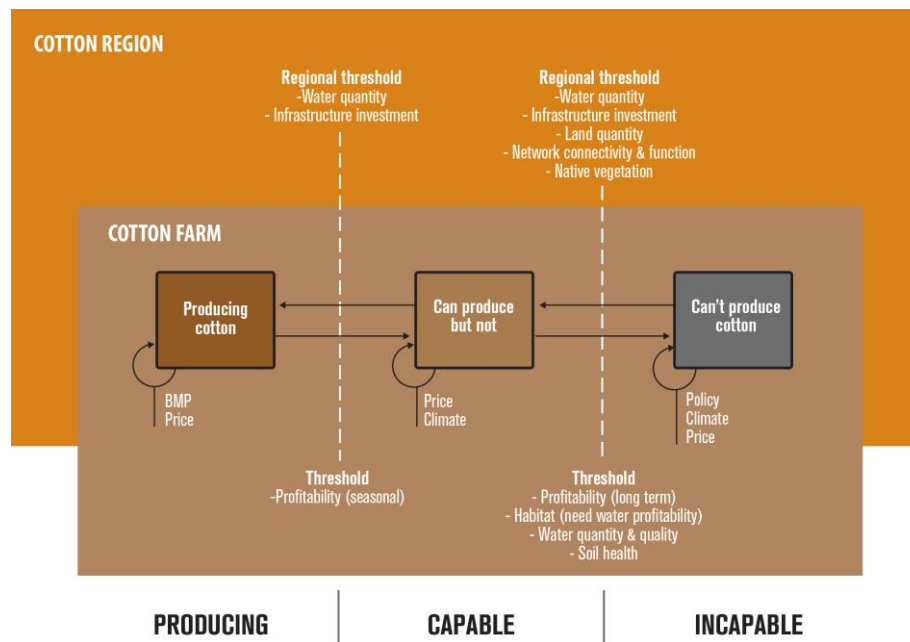


Figure 22. Conceptual model of states at farm scale and threshold interactions with regional scale.

The dynamics between the first two states are fast in relation to price and climate variability. The dynamics between able but not currently producing cotton and unable to produce cotton are much slower in relation to climate change, price and policy. This is reflected in cotton production's distinctive capacity to persist even given high levels of variability (see Figure 23).

More detailed statistics and data highlighting the variability of Australian cotton production are included in [Appendix 16](#).

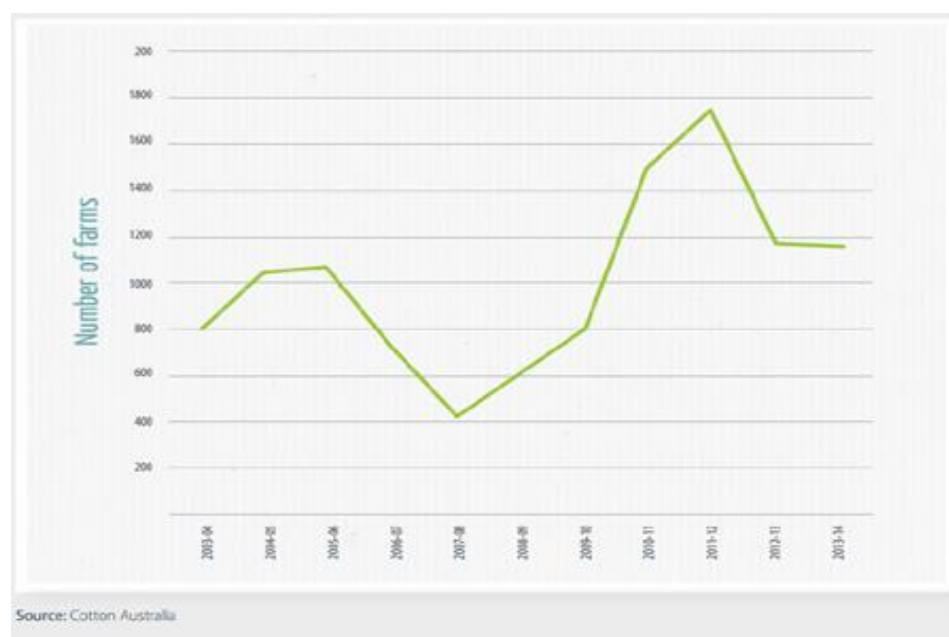


Figure 23. Number of cotton farm units.

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In 2012 the **average**⁶² Australian cotton farm⁶³:

- was family owned and operated
- provided jobs for eight people
- grew 656 ha of cotton
- was run by farmers with an average age of 39
- had very experienced operators, with over 75% having 15 years' experience or more
- were mixed farming operations
- had less than half of its area cultivated (40%).

In 2012, cotton provided employment for 8,000 people across northern NSW and southern Queensland⁶⁴.

Given that not all land is suitable for irrigation, most cotton-producing farms are mixed enterprises of irrigation and dryland grain production systems and cattle. Cotton is often the main irrigated crop on these mixed farms. Melons, vines and citrus may share the irrigation facilities. Chickpeas, sorghum, canola and wheat (rarely if ever irrigated) are the main alternative or additional crops.

*'While cotton is the main economic crop, the farms are also significant producers of rotation crops including wheat (bread, soft and pasta), canola, chickpeas (Garbanzo), sorghum and smaller quantities of some specialist seeds.'*⁶⁵

Desired state

CRDC's desired outcomes at the farm scale, as stated in its strategic plan, centre on a 'profitable future'. As such, much of the literature produced by CRDC about farm-scale change is focused on profit, especially how to increase yields. This said, it also includes notes on factors such as business strategies and financial risk management.

As the regularly produced cotton production manuals indicate⁶⁶, CRDC also publishes research on how to improve industry sustainability over a slightly longer term, including managing pests, weeds, diseases, chemical resistance, soil, water, biodiversity and workplace health and safety. These also have implications at the regional level, as biological challenges spread, and at the national level, in terms of the industry's reputation for being innovative and proactive, fitting well with their desired outcomes for sustainable futures at the industry level.

As is often mentioned throughout industry reports, the industry is known for, and desires, high levels of research, development and adoption. On average, cotton farmers are younger and more likely to have tertiary qualifications than farmers in other agricultural industries⁶⁷, which might contribute to this capacity for innovation. A high proportion of growers in recent seasons have also been new to cotton.

⁶² Note that it is hard to generalise on any parameter related to the crop size as it is very dependent on annual meteorological conditions. Averages hide the large variation from year to year, and so the description of the 'average' farm above hides many variations.

⁶³ <http://cottonaustralia.com.au/cotton-library/fact-sheets/cotton-fact-file-the-australian-cotton-industry>

⁶⁴ Stubbs Report, 2012

⁶⁵ <http://www.auscott.com.au/Farming/default.aspx>

⁶⁶ Cotton Info Team (2014) *Australian Cotton Production Manual 2014*. Cotton Info Team
Cotton Info Team (2015) *Australian Cotton Production Manual 2015*. Cotton Info Team

⁶⁷ *Australian Grown Cotton Sustainability Report 2014*

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CRDC's focus on best management practice, in both online and print resources, and the general tendency for high adoption, may have contributed to the industry's success thus far, and are certainly viewed that way by stakeholders as reported in the reports reviewed.

Top performers in the *Australian Cotton Comparative Analysis 2013*⁶⁸, based on consultation with growers, were defined in terms of yield per hectare, rather than price, as they felt price would distort information about best growing methods. This implies that growers see yield of cotton as an important part of the 'desired state', and the authors of the comparative report make this explicit: "The central question for growers should be 'How can I improve yield as cheaply as possible?'" , noting too that a yield increase also has to be a financially sustainable choice, considering the cost of investments.

⁶⁸ Boyce Chartered Accountants (2014). *Australian Cotton Comparative Analysis 2013 Crop*. Report to Cotton Research and Development Corporation

General resilience

General resilience in this study is defined as: *the capacity to manage unknown or unexpected events*.

General resilience, sometimes called adaptive or coping capacity, is the capacity of a system, whether it is a business, region or industry, to manage unknown risks when they arise. There are several attributes of general resilience, which when assessed give an indication of the adaptive capacity of the system as a whole to deal with shocks and unexpected changes. The key general resilience attributes that have been investigated in this assessment are described in Table 10.

Like specified resilience general resilience can be assessed at different scales. In this study it was assessed at the farm, region and industry scales.

Table 10. Attributes of general resilience assessed for the cotton industry.

General resilience attributes	Measures and examples of this attribute
Capacity to self-organise	- social networks - organisational skills and capacity - leadership - trust
Capacity to respond to short term crisis	- support networks - access to reserves of capital - clear roles and responsibilities - memory and experience of past events - training opportunities and pre-planning
Capacity to make change at the appropriate scale and time (power, influence and agency)	- suitable governance and institutional arrangements that allow flexible and adaptive approaches, at the right scale - deliberate learning approaches
Capacity to innovate	- support for research and development - transfer of new knowledge and skills - learning from practice - immigration of people, technology skills and capital - support for innovation
Diversity	- business types – corporate, family, size - approaches, ideas and innovations - income and livelihoods - ecosystems, land types and soil types
Degree of overlaps (positive redundancy)	- overlaps between institutions and organisations (i.e. some cross membership, shared responsibilities and roles) - shared understanding and mental models of dynamics, risks
Modularity	- Degree of connectivity which enables or hinders the transmission of shocks through the industry, measured for example by the ease with which disease or weeds, or new farming techniques, could be spread.

Methodology

Attributes of general resilience are most often assessed qualitatively, an approach used in this study⁶⁹. Two surveys were conducted to understand how the industry perceived its general resilience and adaptive capacity and inform this resilience assessment.

Survey 1. A sample of industry members from all regions and all sections of the industry were surveyed at the 2014 Annual Cotton Conference. Two of the questions were relevant to general resilience. One question asked how well industry members believed the industry responded to sudden crises, and the other required respondents to nominate what they thought of as the major strength of the industry.

Survey 2. A more detailed questionnaire was developed which asked a greater number of questions about the range of general resilience attributes at all three scales; farm, region and industry. This questionnaire was answered by three groups; the reference panel (five responses); the workshop participants (24 responses); and the industry workshop participants (ten responses)⁷⁰.

Members of the reference panel answered questions for Survey 2 at all three scales, grower workshop participants answered questions at a farm and regional scale and industry workshop participants answered questions at an industry scale.

The reference panel members and the industry workshops participants not only provided estimates of the level of various attributes but also estimated the trend in each attribute. The grower workshop participants only estimated the level of each attribute.

The survey asked respondents to assign a level between 1 and 5 to each attribute. Up to five questions were asked for each attribute to gain deeper insights into respondents' views. As an example, the 'capacity to self-organise – leadership, power and trust', was assessed by asking respondents to answer five separate questions:

1. Presence of social networks for people managing and running the cotton farm.
2. Presence of organisational skills and capacity to address issues as they arise.
3. Processes in place to develop and support leadership.
4. Ability to influence decisions.
5. Levels of trust between individuals and organisations involved in running the farm.

For the questions, results and analysis of Survey 1 go to [Appendix 17](#). For the complete questionnaire for Survey 2 (farm and region scale) go to [Appendix 18](#).

⁶⁹ For an example of a quantitative approach to assessing general resilience in a region, refer to Strategic Economic Solutions and Bugseye (2014). *North West Local Land Services General Resilience Attributes*. Compilation prepared for NWLLS

⁷⁰ The survey was qualitative. The sample size was not chosen with the aim of generating a statistically significant response but to generate insights into the industry's perception of its general resilience.

Findings

In general, all respondents had similar views on the resilience of the industry at all three scales. The responses from people in the regional workshops did not differ markedly from one another and their responses at the farm and regional scale were similar to the responses from the reference panel. The responses from the reference panel and the industry workshop participants were also similar.

Capacity to self-organise

The industry believes it has medium to high capacity to self-organise. People feel that there are the skills, social networks and leadership to meet future challenges. As well, respondents felt there are good levels of trust between industry members and that they had the capacity to influence and take part in decision making.

There was no agreement on the trends associated with this attribute; some respondents believed that the capacity was increasing while others thought that the same capacity was decreasing.

Text analysis of the responses from respondents at the cotton conference supports the view that the industry has a high capacity to organise itself. The responses to the question of the industry's greatest strength are shown in Figure 24 where the size of the word indicates the frequency of response.

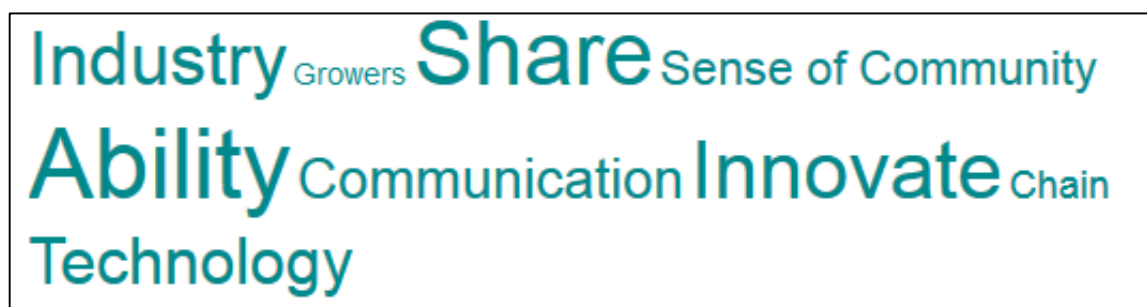


Figure 24. Responses to a question on the greatest strength of the cotton industry.

The overall results were similar at a regional scale as for the farm scale with a perceived high ability to self-organise. Respondents believed there was less trust between key individuals and organisations and less ability to influence decisions.

There was no agreement between respondents on the trend of this attribute.

The views at farm and regional scale were reflected at the industry scale with respondents perceiving that the industry has a high capacity to self-organise. No clear trend was apparent with conflicting views on whether this capacity was increasing or decreasing.

Capacity to respond to short-term crises

There is a medium to high capacity to respond to short-term crises. It was also felt that the industry had responded well to previous crises. While industry felt there was good capacity to respond to crises, respondents indicated that key resources were decreasing which could

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have an impact on the industry's capacity to act in the future. On the one hand it was felt that financial reserves, natural reserves, and industry corporate memory were decreasing, while on the other hand it was believed that monitoring to identify potential critical issues was improving.

Again, there was little difference between the perception of the capacity of the industry to respond to short-term crises between the farm and the region responses. At a regional scale it is believed that there is less financial capacity to respond to short-term crises.

Respondents appear to be more confident of the industry's ability to respond to crises than at the regional and farm scale. There appears to be more confidence that the resources exist at this scale to give the industry a high capacity to respond to crises.

Capacity to make change at the appropriate scale and time (power, influence and agency)

The results for this attribute were similar to the previous attribute indicating that there is good capacity to make changes at all scales. Respondents believed they had the necessary power, influence and control to make appropriate changes.

There was no major difference in the results across the scales with the 'scores' at the industry scale only slightly higher than at the farm and regional scales.

Capacity to innovate

There is a high capacity to innovate in the industry associated with a strong commitment to research and development and support for innovation but respondents felt that there is less influence from ideas, knowledge and people coming into the industry from outside.

As with the previous attribute there is a perception that there is greater capacity at the industry scale to innovate and adopt new ideas.

Again, it was not possible to identify a consistent trend for this attribute.

Diversity

This attribute scored the lowest of all attributes, especially for social, cultural, ecological and biophysical diversity although it was felt there is a good diversity of approaches and innovation on farm.

There appears to be less diversity at an industry scale than at the regional and farm scales.

It was not possible to identify a consistent trend for any aspect of diversity.

Degree of overlaps (positive redundancy)

The degree of positive redundancy varied with each question. There was low overlap on farm for roles and responsibilities but perceived high overlap for how major problems were perceived. Individual responses on the degree of dependence on a single enterprise varied from very low to very high, which probably reflects individual farm circumstances.

No trend for any aspect of the attribute could be determined.

Modularity

Modularity reflects the characteristics that determine how rapidly drivers or shocks can spread through a system, i.e. how connected or disconnected different parts of the system are. Responses to this question varied from very low to very high. The average scores from all respondents, greater than 3, suggest that there is a high degree of connectedness between farms and regions and even across the industry and that both undesirable shocks or positive innovations to address new challenges could be spread rapidly throughout the industry.

Implications

Assessing general resilience is similar to trying to assess the strengths or weaknesses of the system. All of the sources of information and data reviewed for this project support the view that the cotton industry is well organised and confident of its own ability to manage and cope with change and issues as they arise. It also believes in its ability to innovate, secure resources and influence decisions, particularly at a farm and regional scale. Views of respondents to the general resilience surveys are supported by the existence and effectiveness of the research and development sector of the industry and the way in which the industry adopts new practices. These are undoubtedly industry strengths.

The industry is also aware of its relative lack of diversity. Because it is based on a single commodity, the industry will always be vulnerable to sudden shocks such as a sudden price fall or a disease outbreak. If this occurs, its connectedness (or modularity), which is a strength when it comes to practice adoption, becomes a weakness.

The industry perceives it has a high capacity to make changes and influence decisions but, in reality, for some of the major issues identified in this study, e.g. climate variability and water availability, it has little choice but to adapt to a changing environment. The industry also has little ability to influence government policy at a state or federal level and it operates in a world market that determines the prices of cotton itself and diesel fuel. It is important that the industry understands the limits of control.

Cotton production is a good example of a modern agricultural system that relies on high inputs and smart technology to achieve high levels of production. This is another reflection of the relative lack of diversity in the system. Some possible responses to this lack of diversity might include:

- ensuring a greater variety of varieties are grown each season by choosing varieties with characteristics suited to different regions
- looking for alternative sources of supply of seed
- continuing to look for greater diversity in the sources of energy to drive machinery or adapting machinery to use different energy sources

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- developing production systems for other environments
- encouraging and maintaining a greater diversity of growers.

Industry business types have become less diverse over time as family businesses struggle to invest in technology and achieve economies of scale to offset declining terms of trade. This trend towards fewer farms growing more cotton and a greater proportion of cotton grown by corporate farms means the overall diversity of the industry is decreased.

Hyper-connectivity between properties with contractors and equipment moving from property to property has the potential to spread a new disease rapidly and widely. Capacity to influence many of the key drivers and dynamics of the industry is limited. Building adaptive and transformative capacity to respond to these dynamics should be considered.

To spread risk, many farms diversify (the diversification trade-off). Cotton accounts for less than a quarter of the farming area in any one year on an average property. The area planted to cotton varies with seasonal conditions and prices, and growers opportunistically take advantage of good conditions.

Diversifying spreads risk and improves resilience. To be viable, however, cotton production needs to be done well, which requires high levels of skill, input and technology, something that is inconsistent with opportunistic farming. The complexity, skills required, the level of fixed and variable costs and compliance associated with cotton growing are likely to increase in the future. The diversification trade-off probably introduces some level of new risk for farm businesses that may not always offset the original rationale for diversifying.

There are trade-offs also between resilience at farm, region and industry scale. For example, increased technology and mechanisation at the farm scale to improve the resilience of farm businesses coupled with aggregation of properties to achieve economies of scale reduces labour requirements, which in turn reduces rural community populations in some areas with flow on effects to services. These changes can have flow-on effects to the regional scale, some of which reduce the resilience of regional communities.

Interventions

This resilience assessment is being undertaken to assist the Australian cotton industry, and CRDC in particular, to prioritise interventions and direct its effort and investment. It is important to note that these interventions are proposed as a starting point to promote discussion and help inform CRDC planning processes rather than as a definitive action plan. Implementation and adaptive management is part of Phase 6 of the resilience assessment process, which will be undertaken by CRDC as part of ongoing planning, implementation and adaptive management (see [Appendix 2](#)).

The purpose of any resilience assessment is to identify systemic risks that, if not addressed, can result in changes in the system from a desired to an undesired state. Interventions based on managing these systemic risks are targeted towards two key categories of systemic risks. These are specified resilience issues linked to managing thresholds, and general resilience issues related to managing the general capacity of the system to cope with unknown or unexpected risks.

In most cases, both types of risks need to be managed; focusing on one or the other can lead to an inadvertent loss of resilience of the whole system. For this reason, it is important to consider both specified and general resilience issues when testing assumptions and designing interventions.

Intervention types

There is a range of ways to intervene in any system. Table 11 is an outline of leverage points for intervening in a system. These types of interventions are presented to provide insights into the potential interventions proposed by the Australian cotton industry in general and CRDC in particular.

Table 11. Types of system interventions.

Type ⁷¹	Complexity	Description
Variables	Lower	Changing variables such as parameters, constants or numbers within the existing system (such as subsidies, taxes, or industry standards)
Buffers		Changing the size of buffers and other stabilizing stocks, relative to their flows
Structure		Changing the structure of material stocks and flows (such as transport network, population age structures)
Lag time		Changing the length of delays or lag times, relative to the rate of system changes
-ve feedback loops		Changing the strength of negative feedback loops, relative to the effect they are trying to correct against
+ve feedback loops		Creating gain around driving positive feedback loops
Information flow		Changing the structure of information flow (who does and does not have access to what kinds of information in particular)
Rules	Higher	Changing the rules of the system (such as incentives, sanctions, constraints)
Power		Changing who or what has the power to add, change, evolve, or self-organize system structure
Goals		Changing the goal of the system
Paradigm		Changing the whole mindset or paradigm that the system arises from (i.e. goals, structure, rules, delays, parameters)

Rationale for intervention in specified resilience

The rationale for intervention in specified resilience should be targeted at managing key thresholds. There are three main issues to consider, as follows:

1. Which thresholds?

These should be prioritised based on the potential for:

- The level of *impact* crossing the threshold will cause – in terms of cost, both directly and indirectly, by causing a cascade of other thresholds being crossed through the system, based mainly on the degree and number of connections between thresholds within and between scales. Higher levels of impact should be given higher priority.
- *Time for recovery* - time lag for response (with and without the intervention) and the knock-on systemic consequences of such lags. Those issues with slower recovery times should be higher priority.
- *Feasibility* – which thresholds can be managed with currently known technologies. Those issues that have technically feasible interventions options available now

⁷¹ Meadows, D. (1999) *Leverage Points. Places to intervene in a system*. The Sustainability Institute, Hartland, VT

should be given higher priority than those without currently available intervention options.

- *Risk of unintended consequences* – could there be unintended consequences from the interventions? Those with a lower risk of unintended consequences should be considered before those with higher risk.

2. When should the intervention occur?

- *Probability of crossing threshold* - priority can be determined by the likelihood of crossing the threshold within a defined time period (proximity to the threshold + rate of trend), where the system is close to the threshold or has a clear trend towards a threshold and hence is likely to cross the threshold before those that are further away and have minimal or slow trend towards the threshold.
- *Sequencing* – addressing thresholds in a logical sequence to address nested thresholds or causing unintended consequences. More ‘foundational’ issues should be addressed first.

3. How should the intervention be delivered?

The most effective interventions are those that change the ‘context’ around a threshold. In practice, there are only a few mechanisms for delivering interventions aimed at changing the dynamics around a threshold. These can be summarised into three categories, as interventions that address:

- *Knowledge* – such as new research and development, better distribution of existing technical knowledge through education and awareness and improved learning through monitoring, evaluation and reflection to inform practice.
- *Rules* – creating subsidies, incentives or disincentives through financial support or taxing, regulation to support actions.
- *Values* – changing the way people or communities think about problems or issues, their paradigms, values and perceptions and influencing norms around practice or beliefs about issues such as climate change.

Determining priorities for addressing thresholds

No single criteria can determine exactly which thresholds should be addressed, rather a mix of factors must be considered. Even where a precise sequence of interventions can be identified, ‘external’ factors such as the availability of resources, skills, capacity, political or community support for change, specific economic and climatic factors could determine which intervention actions are realistic at any particular time. As a general guide, however, thresholds that have the following set of characteristics should be addressed first:

1. Higher impact
2. Higher probability of crossing threshold
3. Slower recover time without intervention
4. Earlier sequencing requirement.

This would suggest addressing **national research and development**, **regional water availability** and **regional infrastructure**, **farm profitability** and **farm water availability** should be the highest priorities for interventions.

Intervention points for specified resilience

Table 13 is an initial desktop assessment of intervention points for specified resilience (known thresholds) for the Australian cotton industry at three scales (see Table 1, page 7). It is important to note that this table is indicative; some of the ratings for some categories are based on desktop analysis and there are some data gaps that need more analysis before a more definitive set of interventions could be identified. Detailed interventions should be identified by industry experts in collaboration with growers and other industry participants. Table 12 below provides explanation of the ratings used in Table 13.

Table 12. Ratings used in identifying interventions.

Category	Rating
Impact	- High – crossing the threshold would cause major disruption and incur significant losses and costs for the industry - Medium – crossing the threshold would cause moderate disruption and incur losses and costs for the industry - Low – crossing the threshold would not cause any significant disruption or loss for the industry
Recovery time	Fast – with or without intervention would occur in < 3 years
Without intervention	Moderate – with or without intervention would occur in < 3 to 10 years
With intervention (in brackets)	Slow – with or without intervention would take > 10 years for the recovery to occur
Feasibility	- High – high confidence, the technology/knowledge exists - Medium – medium confidence, some of the technology/knowledge exists - Low – low confidence, the technology/knowledge does not currently exist
Risk of unintended consequences	- High – there is likely to be major unintended consequences from the intervention - Medium – there could be major unintended consequences from the intervention - Low – there is unlikely to be any major unintended consequences from the intervention
Priority (likelihood of crossing threshold)	- High – high probability the threshold will be crossed in the near term (1 to 5 years) - Medium – the threshold is likely to be crossed in the medium term (5 to 10 years) - Low – the threshold could be crossed at some time in the future
Sequencing	- Earlier – the intervention is foundational, supporting later interventions so needs to occur before others - Later – the intervention is not foundational so does not need to occur before others

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Table 13. Specified resilience interventions.

Scale	Threshold	Impact	Recovery time without (with) interventions	Feasibility	Risk of unintended consequences	Probability of crossing threshold	Sequencing	Examples of potential interventions
Industry	R&D investment	High	Slow (Fast)	High	Low	Low	Earlier	- invest in changing values and perception of growers around the levy (to allow for potential changes in the levy as public and commercial investment changes) - invest in influencing the values of other funders of R&D including government, industry and private - invest in synthesis of existing knowledge - audit knowledge needs, gaps and emerging issues
	National networks	Medium	Fast (Fast)	High	Low	Medium	Later	- survey and network analysis to understand network structure and connectivity and flows at regular interval, particularly in new growing areas
	Social License	High	Moderate (Fast)	Medium	Medium	Low	Earlier	- invest in understanding community perceptions of cotton growing practices - invest in influencing values of the role of cotton in society

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Scale	Threshold	Impact	Recovery time without (with) interventions	Feasibility	Risk of unintended consequences	Probability of crossing threshold	Sequencing	Examples of potential interventions
Region	Regional Infrastructure	High	Slow (Slow)	High	High	Medium	Earlier	- invest in lobbying key stakeholders about ongoing investment in regional infrastructure (values) - invest in lobbying for guaranteed supply of regional infrastructure
	Water quantity	High	Moderate (for policy driven declines) (Moderate) Moderate (for climate driven declines) (Moderate)	High	Low	Low	Earlier	- invest in knowledge and values relating to climate policy - lobby policy makers around water policy and bulk allocation rules - lobby stakeholders to change values relating to water
	Land availability	Moderate	Slow (Fast)	High	Low	Low	Earlier	- synthesise existing knowledge on rates and implications of land use change - lobby for protection of high value agricultural land in legislation
	Regional native vegetation	Low	Slow (Slow)	High	Low	Moderate	Later	- investigate incentives for protection and re-establishment of native vegetation cover and connectivity - invest in regional capacity for vegetation management (regional equipment, skill, seed resources) - influence values and perceptions of values of regional vegetation cover

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Scale	Threshold	Impact	Recovery time without (with) interventions	Feasibility	Risk of unintended consequences	Probability of crossing threshold	Sequencing	Examples of potential interventions
Farm	Profitability	High	Moderate (Moderate)	High	Low	Moderate	Earlier	- audit farm financial management capacity - investigate farm financial position of growers under different conditions - invest in farm financial skills and capacity - provide farm financial services - investigate alternate farm finance models - invest in lobbying for changes around farm finance models and farm assistance packages
	Water quality	Moderate	Moderate (Moderate-Slow)	High	Low	Low	Earlier	- maintain monitoring of water quality
	Water quantity	High	Moderate (for policy driven declines) (Moderate) Medium (for climate driven declines) (Slow)	High	Low	Medium	Earlier	- invest in 'climate ready' irrigated cotton strains - continue to invest in BMP and on-farm water use efficiency - invest in on-farm decision support tools around water/production decision making
	Soil health	Moderate	Slow (Moderate)	High	Low	Low	Earlier	- maintain and update BMP - invest in monitoring soil health - investigate low input farming practices

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Scale	Threshold	Impact	Recovery time without (with) interventions	Feasibility	Risk of unintended consequences	Probability of crossing threshold	Sequencing	Examples of potential interventions
Farm	Native vegetation	Low	Slow (Slow)	High	Low	High (most farms are at or below critical thresholds already)	Later	- maintain and update BMP - influence values and perceptions of the value of on farm vegetation cover - explore incentives for maintaining vegetation at farm scale - monitor vegetation health at farm scale

Intervention points for general resilience

Intervention points for general resilience are harder to identify. There were no clear trends identified for the general resilience attributes assessed. The level of most attributes is also considered adequate by those in the industry. This is not necessarily only a reflection of the resilience of the industry (which is high in relation to many of the general resilience attributes), but also reflects some of the challenges of applying general resilience concepts at a range of scales.

In some cases, there are some differences at scale (such as **degree of overlaps/positive redundancy**) but these are probably indicative of individual circumstances. The issue of chemical resistance and reliance on one main herbicide has been discussed in the specified resilience analysis, but it also relates to the general resilience attribute of **diversity**. Diversity is considered low in relation to control options, which are currently limited.

Modularity emerges as a priority for consideration for both general and specified resilience. This is particularly relevant for the potential spread of biosecurity threats. Options for intervention are:

- to maintain some geographic separation where possible at a range of scales
- implement best practice hygiene (such as the *come clean, go clean* program)

Consistent use of best practice hygiene is always a challenge across any industry and cotton is no exception.

It is important to note that while modularity has emerged as the priority attribute for attention, the cotton industry should remain vigilant by including a range of general resilience considerations in their choice of indicators.

Indicators

Indicators are important for tracking progress, reporting against agreed targets and communicating with consumers and policy makers about industry achievements. The Australian cotton industry has been focussed on developing appropriate indicators to better track sustainability of cotton production in recent years⁷². CRDC's sustainability indicators have been reviewed as part of this resilience assessment.

Resilience indicators in general

Using indicators to monitor the resilience of systems is a recent development. An issue is that it is difficult to identify suitable indicators to track resilience given that our understanding of complex adaptive systems is never complete because of their dynamic nature and the approximate systems models against which measurements are made.

What is accepted is that resilience indicators should help to track system dynamics relative to desirable system states, they should promote an understanding of proximity to critical thresholds and they should help evaluate how a system is being managed⁷³.

Based on examples from across a range of sectors, the following issues have been identified as important when developing resilience indicators⁷⁴:

- Simplifying complex concepts is challenging. A narrow set of indicators or simplified units of measurement risk blocking the deeper understanding of system dynamics needed to apply resilience thinking and inform management actions. Managers need to be aware of these trade-offs when developing and monitoring indicators.
- There is a risk in simply repackaging existing indicators, particularly if the limitations and trade-offs are not acknowledged and addressed. Indicators should be derived using the same thinking that underpins the assessment. Applying the same thinking makes it possible to select indicators of resilience while making explicit the underlying assumptions. This will help evaluate the impact of interventions and strategies at multiple scales.
- Indicators should be adaptive and regularly reviewed as the system and context, and our understanding of it, changes over time.
- Indicators should ideally be developed and implemented in collaboration with local partners, growers and other industry players.

In 2015 CSIRO were commissioned by the United Nations Global Environment Fund's Scientific and Technical Advisory Panel (STAP) to review and recommend a set of resilience indicators that could be used across a range of United Nation conventions to inform project development and monitoring in agro-ecological systems⁷⁵. A unified set of indicators was

⁷² Roth, G (2010) *Economic, Environmental and Social Sustainability Indicators of the Australian Cotton Industry*. Cotton Research and Development Corporation, University of New England & Cotton Catchment Communities Cooperative Research Centre

⁷³ Quinlan, A. E., Berbes-Blazquez, M., Haider, L. J., and Peterson, G. D. (2015). Measuring and Assessing resilience: broadening understanding through multiple disciplinary perspectives. *Journal of Applied Ecology*. doi: 10.1111/1365-2664.12550

⁷⁴ Quinlan *et al*

⁷⁵ O'Connell, D., Walker, B., Abel, N., Grigg, N. (2015) *The Resilience, Adaptation and Transformation Assessment Framework: from theory to application*. CSIRO, Australia

Grigg, N., Abel, N., O'Connell, D., Walker, B. (2015). *Resilience assessment desktop case studies in Thailand and Niger*. CSIRO, Australia

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seen as a way to better align effort and track outcomes across disparate issues, programs and projects. As part of the work, CSIRO reviewed the available literature on indicators focusing in particular on resilience indicators.

While the review identified a range of possible simple and complex or compound indicators that could be used to track the resilience of complex human-ecosystem interactions, the authors stressed that the most useful and powerful indicators are those that are developed with a fuller understanding of the local context and dynamics to ensure the indicators best reflect the system. To this end they recommended a process for assessing the resilience of agro-ecological systems before identifying indicators. This is the process used to complete this resilience assessment of the Australian cotton industry at multiple scales.

In short, the process involves assessing the resilience of a system to identify critical variables for thresholds and general resilience. These variables are likely to be different for any particular context⁷⁶.

The following criteria is recommended as a guide for developing indicators:

1. Ensure there is a clear and explicit statement of the intended purposes, and check that the indicators are fit for these purposes.
2. Ensure that the indicators are consistent with the underlying theory and behaviour of the system the indicators are intended to provide information about.
3. Check the tractability of implementation, including replicability, operator bias and competence required.

Given the challenges of finding direct indicators for complex socio-ecological systems, there is also a case for using a combination of direct indicators and surrogate or proxy indicators⁷⁷. Deciding which indicators to use should be based on how available data can provide a snapshot of statistics and trends. Carpenter *et al.*⁷⁸ recommend using 'surrogates' instead of 'indicators', acknowledging that 'important aspects of resilience in socio-ecological systems may not be directly observable, but must be inferred directly'. Surrogate indicators, just like direct indicators, need to be consistent with resilience theory and long-term observations of the system of interest.

Potential resilience indicators for the Australian cotton industry

Indicators for specified resilience can be derived from the thresholds as a starting point, but it is important to note that these may not always capture some of the changes in system dynamics, such as changes in a slow driver or a controlling variable. Indicators for general resilience are based on the attributes identified and assessed as part of this resilience assessment. For an analysis of potential resilience indicators based on the critical thresholds identified for the Australian cotton industry, see [Appendix 20](#). For an analysis of potential resilience indicators based on the general resilience attributes identified for the Australian cotton industry see [Appendix 21](#).

⁷⁶ Hinkel, J (2011) "Indicators of vulnerability and adaptive capacity": Towards a clarification of the science-policy interface. *Global Environmental Change*. 21:198-208

⁷⁷ For example: Strategic Economic Solutions and Bugseye (2014) *NWLLS Region Socio-Economic Profiles*. Compilation prepared for North West Local Land Services

⁷⁸ Carpenter, S. R., Westley, F & Turner, M. G (2005) "Surrogates for Resilience of Social–Ecological Systems". *Ecosystems* 8:941-944

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The resilience-based systems dynamics approach has already identified a set of general resilience attributes that enhance a system's overall resilience to unknown shocks and drivers of change. These attributes reflect the degree of interconnectivity within the system and the rate and capacity for response to shocks. They are as follows:

- capacity to self-organise
- capacity to respond to short-term crisis
- capacity to make change at the appropriate scale and time (power, influence and agency)
- capacity to innovate
- diversity
- degree of overlaps (positive redundancy)
- modularity.

These have been explored in detail in the previous General Resilience chapter (pages 55 - 60).

These attributes are a useful lens through which to assess the cotton industry's general resilience. The challenge is to identify suitable indicators to reflect changes in these attributes. As an example, the NWLLS investigated which socio-economic indicators would best reflect these general resilience measures, and the findings are embedded in the table in [Appendix 21](#) which explores a set of suitable indicators, using available data, to track general resilience at the industry scale.

As noted in the North West Local Land Services (NWLLS) General Resilience assessment⁷⁹:

'... it is important to note that the data represents the attribute rather than measures the attributes, as none of these socioeconomic resilience attributes have readily available data which tracks them exactly. For some attributes, like diversity, a wide range of data options are available, and the judgement to be made is which to select and why. For others (modularity, for example) the judgement is which existing data sets provide the most suitable proxy measures. Data selection is also influenced by availability and in particular by availability at a local or regional scale. The ABS Census is the most comprehensive data source for small areas, and Census variables have been extensively used in this compilation.'

The NWLLS has proposed a set of indicators on their recent regional assessment of general resilience. The NWLLS region includes some of the key cotton growing regions (Namoi and Gwydir in particular). These general resilience indicators are presented in Table 14 as an example of socio-economic indicators at a regional scale to better understand general resilience.

⁷⁹ Strategic Economic Solutions and Bugseye (2014). *North West Local Land Services General Resilience Attributes*. Compilation prepared for NWLLS.

Table 14. General Resilience Indicators for NWLLS region and for NSW.

Resilience indicator	NWLLS Region	NSW	NWLLS region indicator ranking relative to NSW
Employment diversity	28.8	26.86	Lower
Age diversity	24.5	24.68	Similar
Ethnic diversity	12.8%	44.7%	Lower
Flow on/NRB employment	2.2	4.3	Lower
Age dependency ratio	61.1%	51.5%	Higher
Child bearing propensity	1.2	0.93	Higher
Volunteering	22.7%	16.9%	Higher
Personal well-being (satisfied with future security)	54.6%	?	?
Mortgage debt	33%	40.3%	Lower
Farm debt	?	\$595,686 (wheat sheep zone)	?
Value of agricultural production per resident	\$21,704	\$1,681	Higher
Shift share in agricultural employment	35% of change due to local factors	31% of change due to local factors	Moderate outside influence
Tertiary education	36%	46%	Lower
Managers	17.9%	13.3%	Higher

Review of Australian cotton industry sustainability indicators

The Australian cotton industry developed a set of sustainability indicators⁸⁰ designed to:

- demonstrate economic, environmental and social credibility to supply chain markets, government and policy makers and community (domestically and globally)
- guide research priorities and investment to enable practice change
- evaluate outcomes of research investments
- benchmark current performance trends over time at farm and industry scales
- inform and respond to policy development.

See [Appendix 22](#) for information on the existing sustainability indicators used for ongoing industry monitoring and reporting by the cotton industry.

As part of the resilience assessment of the Australian cotton industry at multiple scales, CRDC's sustainability indicators have been reviewed and assessed to identify which are most useful to provide information on the industry's resilience.

The terms 'sustainability' and 'resilience' are sometimes used interchangeably. While the two concepts complement each other, in practice they focus on different aspects and hence

⁸⁰ Cotton Australia & Cotton Research and Development Corporation (2014) *Australian Grown Cotton Sustainability Report 2014*. Cotton Australia & Cotton Research and Development Corporation

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the indicators used to track sustainability and resilience vary significantly. In this case, using a complementary set of indicators that incorporates both key concepts may be desirable.

Sustainability indicators can provide a broad overarching view about the sustainability goals of a system based on 'average' conditions and using a range of assumptions about trends and dynamics. It is important that sustainability be clearly defined for the specific context if this is to be meaningful.

Resilience assessments and indicators provide a detailed understanding of the complex dynamics of a system as they are at that point in time. In this way, they can provide insights on potential vulnerabilities within the system based on both understood and unpredicted changes and shocks. Resilience assessments are not predictive, rather they help to understand and therefore manage the complex dynamics within a system at a point in time.

Some of the current sustainability indicators can provide some insights into the resilience of the cotton sector, however, they have been developed based on a different thinking and different objectives. As a result, while a cotton production system may be viewed as sustainable (particularly if all assumptions about factors such as climate, price or social licence hold true), it can, in fact, be close to a critical threshold. This means that it could be vulnerable in the face of potential shocks or unknown and unpredicted changes.

The sustainability indicators in Table 15 have been reviewed to identify those that can also inform CRDC on the resilience of the Australian cotton industry. The indicators have been assessed using the following three criteria:

- inform the industry on the resilience of cotton production in Australia
- inform the industry on its general resilience
- track proximity to critical thresholds (specified resilience).

It is important to note that the sustainability indicators contain multiple measures for the same aspect of the industry. These have been collected in several different ways to allow communication and engagement with a range of decision makers and partners about the sustainability of the industry. Most of the sustainability indicators give some information on some of the broader system dynamics but are too generic and not linked to any particular scale to inform any more detailed thinking about the resilience of the system. Being more explicit about the scale they refer to would be of benefit.

When viewed in isolation, some of the sustainability indicators provide limited insights into the resilience of the cotton industry at multiple scales. Conversely, in combination, some of the existing indicators can be useful in terms of resilience, e.g. the number of bales produced might be increasing, but this may be misleading for resilience as this might be part of a broader underlying situation where, for example, soil health is decreasing (even though output is increasing, based on use of inputs such as fertiliser). As a result, in this case the entire system is becoming less resilient and more vulnerable to shocks despite increasing output. If the focus is only on the increasing output, we can miss the underlying systems status in terms of resilience.

The sustainability indicators which overlap most usefully with the critical thresholds identified and key systems dynamics (outputs, drivers and trends in particular) in the resilience assessment are identified in Table 15.

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Table 15. Review of cotton industry sustainability indicators.

Domain	Aspect	Sustainability indicator	Specified resilience ⁸¹	General resilience ⁸²	Comments
Economic	Cotton industry production statistics	Planted area (ha) – irrigated	✓		Provides insights into specified resilience farm profitability threshold when considered in conjunction with dryland area planted, yield and gross margin indicators.
		Planted area (ha) – dry land	✓		Provides insights into specified resilience farm profitability threshold when considered in conjunction with irrigated area planted, yield and gross margin indicators.
		Yield (bales/ha) - irrigated	✓		Provides insights into specified resilience farm profitability threshold when considered together with dryland yield and gross margin/ha. It also relates to the industry scale R & D investment threshold.
		Yield (bales/ha) – dryland	✓		Provides insights into specified resilience farm profitability threshold when considered together with irrigated yield and gross margin/ha. It also relates to the industry scale R & D investment threshold.
		Fibre quality			Given the limited price premium for quality, this is of limited use as an indicator of resilience.
		Metric tonnes of cotton produced	✓		Provides insights into regional infrastructure investment and network connectivity and function, along with industry scale R & D investment which are influenced by the output at farm, region and industry scale.
		Grower numbers			From a specified resilience perspective this is less relevant than the amount of cotton produced at the regional and industry scale. Irrespective of the number of growers involved in producing it, it is the production level that is of most significance. Grower numbers can influence diversity which has implications for general resilience.
		Average/median farm size			Diversity on farm rather than size is more useful from a resilience perspective (as it supports adaptability). Can provide some information on trend of aggregation of farms as part of general system dynamics.

⁸¹ Sustainability indicators highlighted in this column are considered the most useful from a resilience perspective particularly in relation to the dynamics (outputs, trends and drivers) and proximity to specified resilience thresholds identified in the resilience assessment. Further details are provided in the comments column.

⁸² Sustainability indicators highlighted in this column can provide some useful information in relation to the general resilience attributes (levels and trends) identified in the resilience assessment. Further details are provided in the comments column.

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Domain	Aspect	Sustainability Indicator	Specified resilience ⁸³	General resilience ⁸⁴	Comments
Economic	Economic value	Cotton price/bale	✓		Cotton price is a driver at the farm scale and thus interacts with all the farm scale thresholds. Demand (a driver at the regional and industry scale) influences price at the farm scale.
		Gross value of the cotton produced in Australia (\$)	✓		Provides some information on general system dynamics and can be relevant for industry scale social licence threshold. Similar insights are gained from the production statistics referred to above.
		Cotton exports			Provides some insights on general system dynamics. The proportion of the cotton crop exported could be relevant from a resilience perspective at the international scale given the exposure to international demand fluctuations but this is beyond the scope of the resilience assessment completed.
		Cotton's % of region gross value		✓	Provides some information on general system dynamics and regional resilience in general (as opposed to regional cotton production specifically). Can relate in part to industry scale social licence issues. Provides insights into the general resilience attribute of diversity at the regional scale in particular (higher reliance on cotton crop exposes region to crop fluctuations).
		Australia's % share of global cotton lint trade			Provides some insights on general system dynamics. Can provide information on international market trends and demand at the industry scale.
		Cotton proportion of global textile market			Provides some insights on general system dynamics. Can provide information on international market trends and demand at the industry scale. This indicator would only be relevant if the international scale was considered as part of a 'global' scale resilience assessment of cotton production.

⁸³ Sustainability indicators highlighted in this column are considered the most useful from a resilience perspective particularly in relation to the dynamics (outputs, trends and drivers) and proximity to specified resilience thresholds identified in the resilience assessment. Further details are provided in the comments column.

⁸⁴ Sustainability indicators highlighted in this column can provide some useful information in relation to the general resilience attributes (levels and trends) identified in the resilience assessment. Further details are provided in the comments column.

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	Profitability	Gross margin/ha	✓		Provides insights into the specified resilience farm profitability threshold when considered together with irrigated and dryland yield/ha as outlined above.
		Income/ML water	✓		Provides insights into specified resilience farm profitability threshold

Domain	Aspect	Indicator	Specified resilience	General resilience	Comments
Environmental	Soil health	Organic carbon %	✓		Provides insights into the specified resilience farm soil health threshold
		Practice change		✓	Provides some information on general system dynamics and trends in relation to regional expertise and insights into the general resilience attribute of capacity to self- organise.
		Soil sodicity	✓		Provides insights into specified resilience farm soil health threshold
	On farm water use efficiency and productivity	Gross production water use index	✓		Provides some information on general system dynamics and has some relevance to the farm scale profitability threshold
		Irrigation water use index	✓		Provides some information on general system dynamics and has some relevance to the farm scale profitability threshold
		Practice change		✓	Provides some information on general system dynamics and trends in relation to regional expertise and insights into the general resilience attribute of capacity to self- organise.
		Whole farm water use efficiency (%)	✓	✓	Provides insights into specified resilience farm water quantity and quality threshold.
	Groundwater	Groundwater levels	✓		Provides some information on general system dynamics and natural resource trends (which relates in part to farm scale water quantity and industry scale social licence thresholds).
		Groundwater quality			Provides some information on general system dynamics and natural resource trends (which relates in part to farm scale water quality and industry scale social licence thresholds).

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Domain	Aspect	Indicator	Specified resilience	General resilience	Comments
Environmental	Biodiversity/riparian	Area of native vegetation managed under best practice	✓	✓	Provides insights into the specified resilience regional native vegetation cover threshold.
		Vegetation condition and connectivity	✓		Provides insights into the specified resilience farm habitat proximity threshold.
	IPM	Growers using integrated pest management practices		✓	Provides some information on general system dynamics and trends in relation to regional expertise and insights into the general resilience attribute of capacity to self-organise.
	Chemical use	Herbicide use	✓	✓	Provides insights into specified resilience industry social licence threshold along with insights into input trends and profitability threshold at the farm scale and general resilience attribute of capacity to self-organise.
		Pesticide use	✓	✓	Provides insights into specified resilience industry social licence threshold along with insights into input trends and profitability threshold at the farm scale and general resilience attribute of capacity to self-organise.
	GHG emissions	Energy use	✓	✓	Provides insights into specified resilience industry social licence threshold along with insights into input trends and profitability threshold at the farm scale and the general resilience attribute of capacity to self-organise.
		Nitrogen use efficiency			Provides some information on general system dynamics but these are largely addressed in soil health, farm scale profitability and social licence issues outlined above.

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Domain	Aspect	Indicator	Specified resilience	General resilience	Comments
Social	Education	Highest post school qualification of cotton growers		✓	Provides insights into -general resilience attributes of capacity to self-organise and capacity to respond to short-term crisis.
	Employment	Number of people employed on farms		✓	Provides insights into general resilience attribute of capacity to self-organise
		Number of people employed – industry	✓	✓	Provides insights into specified resilience industry scale national network connectivity and function threshold and general resilience attribute of capacity to self-organise
		Number of people employed – regional	✓	✓	Provides insights into specified resilience regional network connectivity and function threshold and general resilience attribute of capacity to self-organise.
	Workplace health & safety	Workers receiving regular health and safety training	✓		Provides insights into general resilience attributes of capacity to self-organise and respond to short-term crisis.
		Workers health and safety programs in place	✓		Provides insights into general resilience attributes of capacity to self-organise and respond to short-term crisis.
	Demographics	Grower age		✓	Provides insights into general resilience attributes of diversity.
		Gender participation in industry		✓	Provides insights into general resilience attributes of diversity.
	Social capital	Australian Cotton Conference delegate numbers	✓	✓	Provides insights into specified resilience industry scale national network connectivity and function threshold and general resilience attribute of capacity to self-organise
		Financial membership in regional Cotton Growers Associations	✓		Provides insights into specified resilience regional network connectivity and function threshold.

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Domain	Aspect	Indicator	Specified resilience	General resilience	Comments
Social	Innovation	Investment levels in R & D	✓	✓	Provides insights into specified resilience industry scale R&D investment threshold and general resilience attribute of capacity to innovate.
		Growers adoption of technology	✓		Provides insights into specified resilience industry scale R&D investment threshold.
	Legal compliance and responsibility	Fines imposed upon cotton SMEs by regulatory authorities	✓		Provides insights into specified resilience industry scale social licence threshold.

Drought case study

This case study reviews the changing scale and nature of cotton production in two regions – Balonne in Queensland and Namoi in New South Wales - from 2000 to 2012 to provide insights into how growers adapted during the drought. It uses cotton industry data and interviews with growers and other business in the cotton supply chain in the two regions.

The case study brings together research and fieldwork done by the authors for three different projects between 2005 and 2012, and provides a recent historical context for the causes and extent of adaptability among cotton growers and other businesses in the cotton supply chain. System adaptability is a key component in resilience assessments, and the Millennium drought provides a valuable case study for the cotton industry.

Climate variability, which includes climatic extremes such as drought, is a key driver of change in the cotton industry at the farm and regional scales. Drought is one of many external shocks that can impact on the cotton industry in Australia, and it is a particularly difficult challenge:

‘Drought is different to other natural disasters in its extended temporal nature. It is difficult to name the start of a drought, and it can last for months or years. This extended temporal nature changes the way a drought impacts on farms, business and communities. It extends the period of anger, frustration and disillusionment, fostering fragmentation of families and communities and withdrawal from shared activities. It extends the recovery period, and also changes the policy responses required.’⁸⁵

The response to drought in these two regions provides further insights into the general resilience of the industry and the significance of identified critical thresholds (specified resilience) on management decisions at the farm and regional scale in particular.

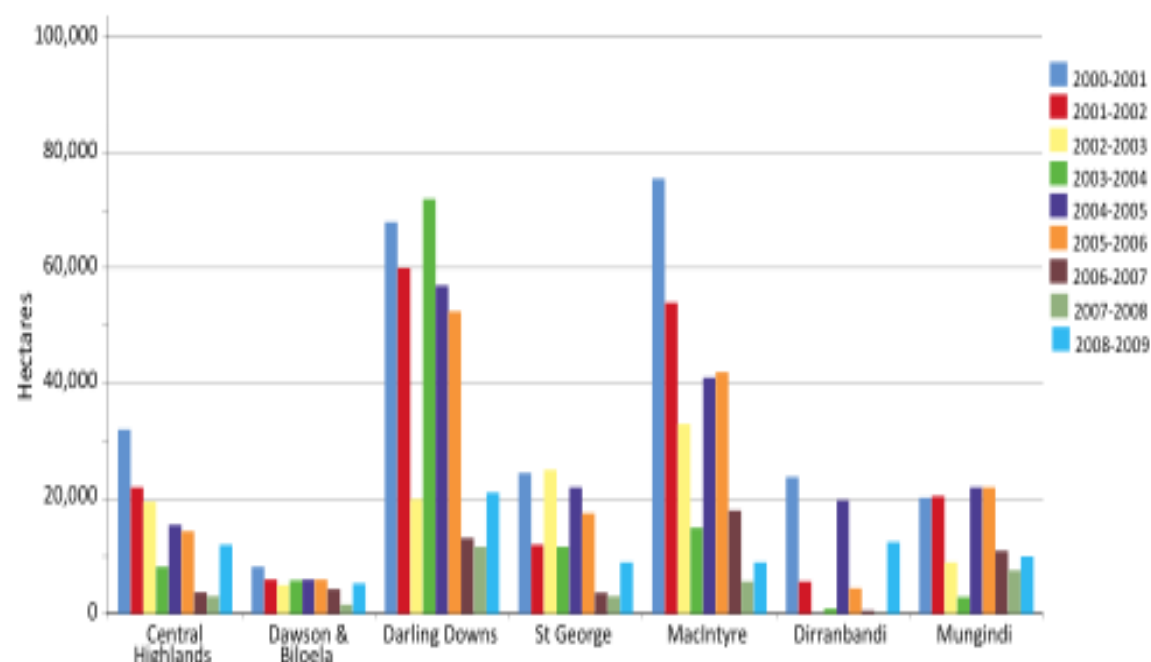
The scale of cotton planting and harvesting in the two regions is summarised below. For more information on the role that cotton plays in these regions go to [Appendix 19](#).

Balonne Shire and St George

In a typical year cotton accounts for over half the value of agricultural production in the Balonne St George region. Cotton plantings and yields can vary significantly from year to year, depending on factors such as water availability, temperature and insect pressure. Figure 25 shows area planted in each of the cotton growing regions of Queensland between 2000 and 2009. In St George/Balonne the area fluctuated between more than 20,000 ha and less than 10,000 ha, while Dirranbandi experienced a year of no plantings in 2002-03 due to drought conditions. Between 2000 and 2008, the number of cotton bales ginned in the St George/Balonne cotton growing region varied from 26,000 to 185,000 with an average of 114,687 bales per season⁸⁶.

⁸⁵ Houghton, K. (2005) *Beyond the Farm Gate: Drought Impacts on Non-Farm Businesses and Communities* by Dr Kim Houghton for Department of Transport and Regional Services (DOTARS).

⁸⁶ Roth, G 2010, *Economic, Environmental and Social Sustainability Indicators of the Australian Cotton Industry*, Cotton Catchment Communities CRC, Australia



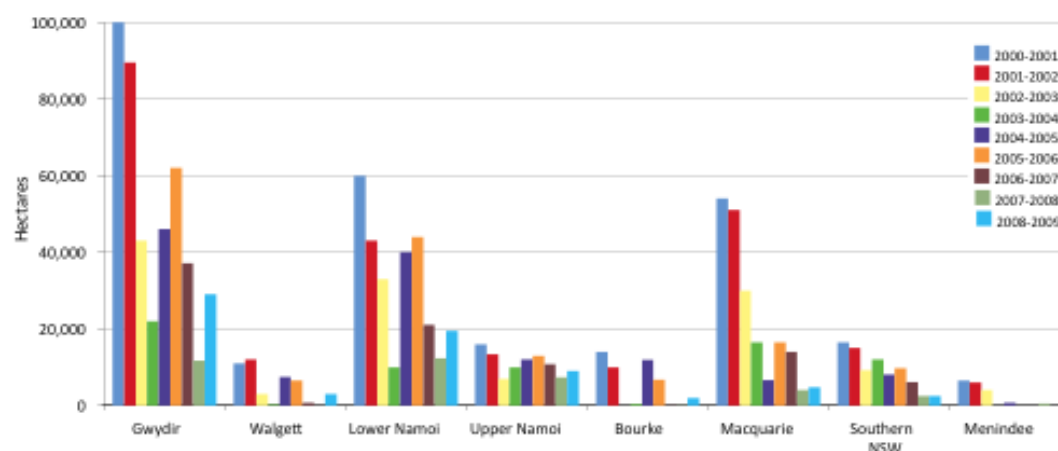
Source: Roth 2010

Figure 25. Queensland cotton regions area planted 2000-09.

Upper Namoi Valley

Cotton in the Namoi is also susceptible to much variability, and cotton plantings and yields vary significantly from year to year. Between 2000 and 2008, production in the Upper Namoi ranged from 56,705 bales to 190,000 bales ginned. The average production over this time was 104,000 bales. In 2006 there were around 45 growers in the Upper Namoi.

Figure 26 below shows area planted in the cotton growing regions of NSW between 2000 and 2009. Compared to the Lower Namoi, cotton production in the Upper Namoi is relatively small but less variable reflecting its diverse agricultural mix and reliable water sources⁸⁷.



⁸⁷ Roth, G 2010, *Economic, Environmental and Social Sustainability Indicators of the Australian Cotton Industry*, Cotton Catchment Communities CRC, Australia

Source: Roth 2010

Figure 26. NSW cotton regions area planted 2000-09.

Cotton planting and harvest variability

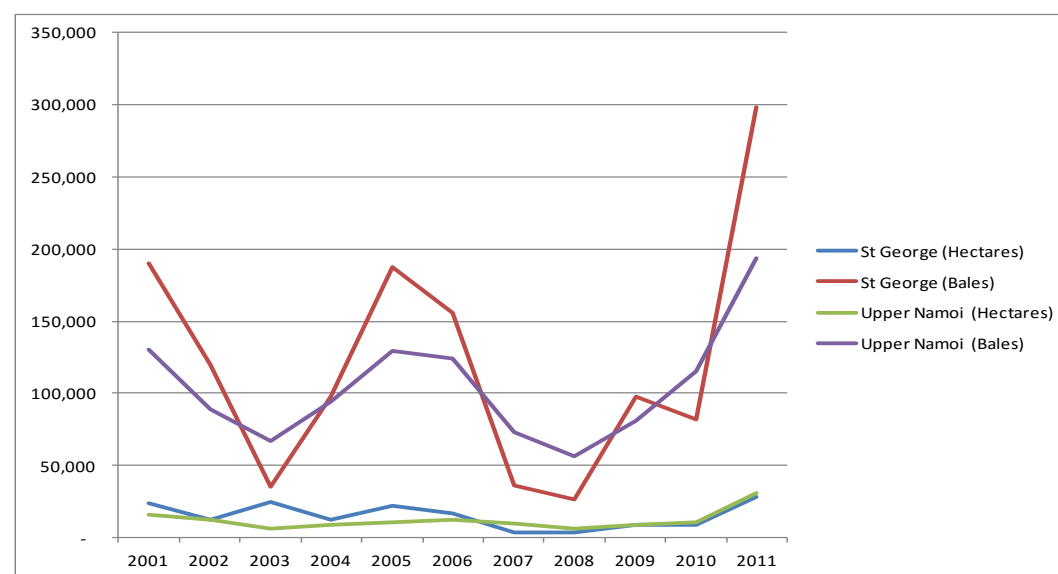
Grower numbers

The number of cotton growers in St George/Balonne was fairly stable over the decade with the number in 2010 in the low 40s following a peak of around 50 in 2003.

The number of cotton growers in the Upper Namoi has also been in the low 40s since a high of 58 in 2004 (and a previous high of 140 in 2001).

Grower activity and productivity

Cotton plantings vary from year to year depending on expectations of water availability and price, weather and cotton prices, as well as on grower business practices and costs. Through the early 2000s areas planted under cotton in the St George and the Upper Namoi regions ranged from 3,500 to 31,000 ha (see Figure 27).



Source: Roth 2010, *The Australian Cottongrower* 2009, 2010, 2011

Figure 27. Case study regions cotton planting area and harvest 2001-11.

The figure shows that the area planted in St George was more variable than in the Upper Namoi, with consequent larger fluctuations in the number of bales harvested. The overall picture shows the extent of annual variability in planting and yield, which ranges from peak to trough in St George of more than sixfold, and more than fourfold in the Upper Namoi. These ranges show the scale of the annual variability in activity which cotton growers and cotton communities have to manage.

The scale of this seasonal variability during the decade is greater for cotton than other crops. For wheat and barley, for example, the seasonal variability was up to 2.5 times from peak to trough, while it was higher for canola – up to 4 to 5 times from peak to trough.

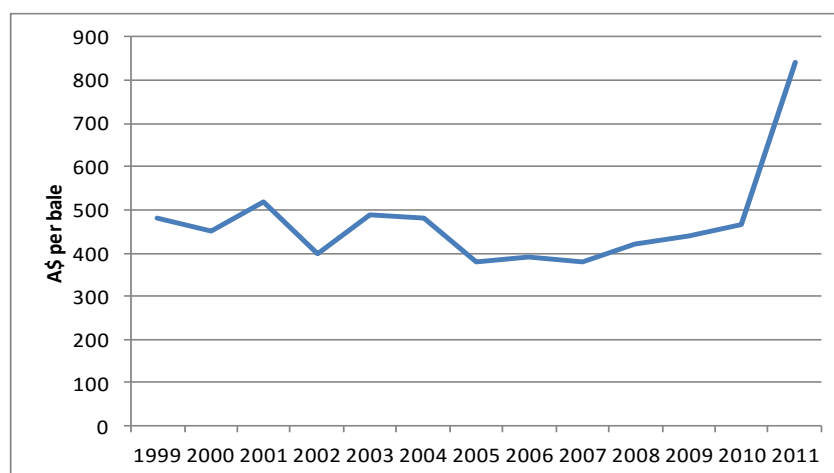
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This is an example of the seasonal profitability (profit per hectare) threshold and the impact that it has on decisions about how much cotton to plant at the farm scale. As outlined in the resilience assessment at the farm scale, this is a nested threshold within the overall profitability threshold which operates over a longer timeframe.

Underneath this variability is a clear trend showing increasing yield per hectare, especially for irrigated cotton. In St George and the Upper Namoi (irrigated) yields increased from around 8 bales/ha in 2001 to around 10 bales/ha in 2011. This confirms the overall trend for increased yields as identified in the resilience assessment.

Long-term average water use nationally is around 9.5 ML/ha, equivalent to 1 ML/bale. Precise water use figures for cotton are hard to compare across regions and years because of the impact of climate (rain and evaporation) and the consequent need for irrigation. Many of those interviewed for this project reported water productivity at between 2 and 3 bales/ML, well above the national benchmark. This further emphasises the importance of water use efficiency and the further gains to be had in relation to water use in cotton production – as highlighted at industry consultation workshops for the resilience assessment.

Cotton price is one driver of cotton planting, but Figure 28 shows that during the drought years the variability in price was much less than the variability in areas planted in the two case study regions. While price is a key driver at the farm scale, as indicated in the resilience assessment, it does not operate in isolation. This highlights the significance of other factors, particularly expectations of water availability in that period.



Source: *The Australian Cottongrower* 2011

Figure 28. Cotton price trend (1999-2011).

Adaptability in supply chains

Focusing on two towns – St George in the Balonne/St George region and Gunnedah in the Upper Namoi - provided detail on the scale and structure of the supply chains.

Figure 29 shows a simple representation of the cotton supply chain in St George and Gunnedah. Cotton moves along the middle line from growers to gins (where fibre is separated from the seed) and then to buyers. The major buyers of Australian cotton (in

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order) are currently China, Indonesia, Thailand, South Korea, and Japan, and there is no government intervention in the growing or marketing of the crop⁸⁸.

Queensland Cotton operates the three gins in the St George/Dirranbandi area, and also provides marketing services to many growers. The Namoi Cotton Cooperative is the main gin operator and marketer in Gunnedah. Most of the services required by the growers in both areas, such as machinery, agronomy and chemical supplies, are provided by local businesses. This reiterates the importance of the skills, infrastructure and machinery at the regional scale as outlined in the resilience assessment. Growers use freight and contract labour from outside sources but in many cases may also provide these services for other growers.

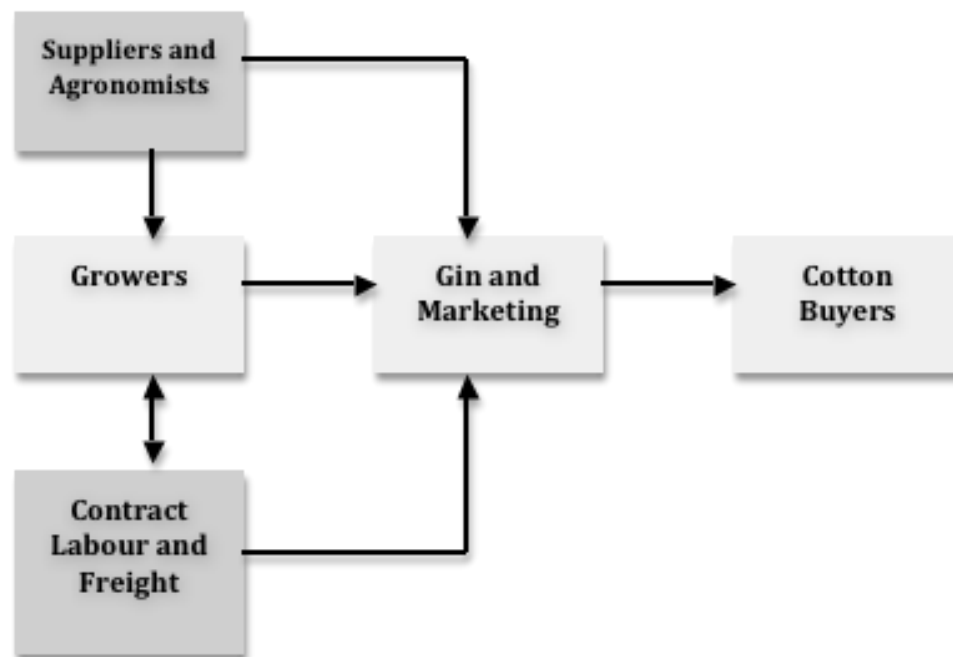


Figure 29. Cotton supply chain schematic.

Cotton businesses in St George

A cross-section of businesses in the local St George cotton supply chain was interviewed for this study. Tables 16 and 17 provide a snapshot of business operations in the area.

In the interviews, each business was asked about how long they had been in business, how important cotton is to their business, typical annual turnover and typical annual employment mix. They were also asked how income and employment had varied between 2001 and 2011.

Note the differences in the importance of cotton to the supply chain businesses (from low in the case of an agronomist to very high for the others) and for the growers (with two having no other farming activities and one having 300 head of cattle). This variation in the extent of dependence on cotton is expected to be replicated across other growers and supply chain

⁸⁸ Roth, G 2010, *Economic, Environmental and Social Sustainability Indicators of the Australian Cotton Industry*, Cotton Catchment Communities CRC, Australia

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businesses, leading to many in the industry being flexible in their year-to-year cotton activity which confers greater resilience on the cotton production system as a whole. This is further supported by the fact that cotton is generally grown as part of a mixed farming enterprise as outlined previously in the resilience assessment.

Table 16. Cotton supply chain businesses, St George.

Supply chain business	Time operating in the area	Importance of cotton production to operation	Average yearly turnover	Employment
Machinery business 1	15 to 25 years	Very important (60-90% of income)	Over \$2 million	18 full time staff
Supply and agronomy 1	More than 25 years	Not important (less than 10% of income). Other activities are grapes, animal health, general merchandise	Over \$2 million	7 full time, 2 casual
Supply and agronomy 2	15 to 25 years	Very important (60-90% of income)	\$30 million	5 full time
Supply and agronomy 3	15 to 25 years	Very important (60-90% of income)	Over \$2 million	3 full time, 1 casual
Aerial spray 1	More than 25 years	Crucial (more than 90% of income)	Over \$2 million	15 full time, 6 contractors (FTE)
Ground spray contracting 1	5 Years	Very important (60-90% of income)	\$250,000 - \$1 million	2 full time, 1 part time
Cotton gins and marketing in St George/Dirranbandi	More than 25 years	Crucial (more than 90% of income)	Over \$100 million	22 full time, 104 casual from March-July plus 9 marketing staff for the entire business (12 gins), 1 for the St George area

Table 17. Cotton growers, St George

Grower	Time farming in the area	Scale of production	Other land uses	Water allocation	Best profit in the last 5 years	Employment
Grower 1	15 to 25 years	178 ha at 12 bales/ha or 1.1 bales/ML	None	2900 ML General Security plus flood harvesting (200 ML used last season)	\$150,000-250,000	3 full time, 8 casual (for harvest)
Grower 2	15 to 25 years	715 ha at 11.3 bales/ha or 1.7 bales/ML	Cattle (300 head)	3360 ML General Security plus flood harvesting (3500 ML used last season)	\$150,000-\$250,000	6 full time, 2 full time contractors, 1 casual
Grower 3	More than 25 years	396 ha at 12.6 bales/ha or 2 bales/ML	None	2300 ML General Security plus flood harvesting (2500 ML used last season)	\$250,000 to \$499,999	3 full time

Managing change

The farmers interviewed in St George were asked about their management decisions in the

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last five years and what they were expecting for the next five years. In the last five years (including some poor seasons) they had all decreased their irrigated area, changed the crop mix of their irrigated production and improved or made plans to improve water efficiency. Planning for the next five years was much less uniform, and all farmers interviewed made the point that often management decisions were not planned but had to be made as a result of water availability and other seasonal conditions.

The following comments highlight how farmers managed the changing situation brought about by the recent drought.

‘Alternative crops were grown in the drought to provide income. Sunflowers, chickpeas and mung beans have all provided good yields. The agronomic ability to move these crops around depending on timing and amount of water available is getting better.’

‘Staff were reduced for a time during the drought, down to one permanent for five to six years. At the lowest point in the drought the farm was down to a hundred hectares of cotton production, and in this year corn and sunflower were also grown.’

‘Machinery is not replaced during the drought. This creates a cost later on.’

Farmers were also asked to predict their actions if water availability (and its impact on cotton related businesses) was decreased or increased by 10, 25 or 50%, respectively. The results are shown in tables 18 and 19. While the sample size is small, it is possible to see a pattern of individual decision making, where small decreases to water availability can trigger changes to crop management, production area and on-farm labour requirements. Large decreases may force sale of assets and seeking other income sources. Conversely, labour requirements and crop management are also affected by relatively small increases.

This highlights the importance of water availability for the cotton industry at the farm, region and whole-of-industry scales. The broad preference seems to be to plant if at all possible, and one farmer commented:

“The area of cotton is decreased only when forced by water availability.”

The interview findings show that farmers adapt to a 10% reduction in water availability with easily implemented changes like changing the crop mix and reducing labour. Even at 25% reduction the actions are similar, though one grower would move to add more off-farm income in this scenario. This suggests that the 10 to 25% variability range is relatively familiar territory to these growers.

Actions change considerably when looking at a 50% decrease in water availability – with a shift to more serious measures like looking for other employment, asset sales and leaving farming or the community.

This pattern was broadly similar to that provided when the scenario was of increased water availability (see Table 19).

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Table 18. How St George growers manage decreased water availability.

	Decrease in water availability		
Possible actions	10%	25%	50%
Increase borrowings	1	1	
Sell business assets		1	
Sell private assets			1
Seek other business income		1	1
Seek other employment			1
Reduce labour	1	1	1
Decrease plantings	1	2	
Change crop mix	1	1	
Sell water	1		
Leave farming			1
Leave community			1

Table 19. How St George growers manage increased water availability.

	Increase in water availability		
Possible actions	10%	25%	50%
Increase borrowings		1	
Repay debt	2		
Buy business assets		1	1
Buy private assets			1
Seek other business income			2
Less employment			
Increase on-farm Labour	1	1	
Increase plantings		2	
Change crop mix	1		1
Sell water entitlements			
Buy water entitlements	1	1	
Leave farming			
Leave community			

In addition to the interviews with growers, businesses in the St George cotton supply chain were asked a similar set of questions i.e. to predict their actions if cotton related businesses decreased or increased by 10, 25 or 50%, respectively. Results for all businesses except the gin are summarised in tables 20 and 21. It can be seen that for decreases in cotton-related business, the trigger point for most actions tended to be higher, i.e. 25 or 50%. Increased cotton business was likely to have positive effects from 10% onwards. These results are supported by comments from businesses about how they managed change during the recent drought, which are summarised in Table 20.

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Table 20. How St George supply chain businesses manage action for decreased cotton.

	Decrease in cotton business		
Possible actions	10%	25%	50%
Increase borrowings			1
Sell business assets		1	1
Sell private assets			1
Seek Other business income	1		4
Seek Other employment			2
Reduce staff		1	3
Move to a smaller premises or reduce operation		1	2
Close the business			1
Leave community			1

The findings for increased cotton production are shown in Table 21.

Table 21. How St George supply chain businesses manage for increased cotton.

	Increase in cotton business		
Possible actions	10%	25%	50%
Increase borrowings	1	1	
Repay debt		2	1
Buy business assets		2	1
Seek Other business income	1	1	
Seek Other employment			
Increase staff	1	2	2
Move to a bigger premises or increase operation	1	1	1
Leave community			

The following comments highlight how business operators in St George managed the changing situation brought about by the recent drought:

“The recent drought greatly impacted this business, which was operating at thirty per cent of where it is at present (after a few good seasons).”

“Business branches in other towns help to insulate and spread risk. No one was fired during the drought, staff can be moved to other branches (although this is not ideal) or simply not replaced when they retire or move on.”

This business is a major agronomy supplier in the area, servicing twenty-five to thirty growers. During the drought the business went back to two to three staff at its lowest point. The business also tried to diversify into other broadacre land uses to maintain income.”

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“The gins have several ways of managing decreased production, including putting off casual workers, reducing operating hours, operating gins at night (off-peak power), diversifying into grain storage, contracting employees to neighbouring businesses, and closing gins.”

“When less gins are operated due to less production, it is at a greater cost to the grower due to increased freight.”

Cotton businesses in Gunnedah

Similar to St George, a cross-section of businesses in the Gunnedah cotton supply chain was interviewed. The cotton supply chain in Gunnedah is similar to that of St George, but many farmers and businesses are more diverse in their operations. Tables 22 and 23 provide information on the nature of interviewed cotton supply chain businesses and growers in Gunnedah.

Table 22. Cotton supply chain businesses, Gunnedah.

Supply chain business	Time operating in the area	Importance of cotton production to operation	Average yearly turnover	Employment
Irrigation supplies 1	1 to less than 5 years	Important (40-60% of income), service about 50 growers, other activities include dairy and effluent piping.	\$2-10 million	6 full time staff, 9 contractors
Supply and agronomy 1	More than 25 years	Small contributor (10-40% of income), service about 20 growers, other activities are broadacre cropping and fallow.	\$2-10 million	10 full time
Cotton gin and marketing 1	15 to 25 years	Crucial (more than 90% of income), about 35 growers serviced. Marketing includes 6 buyers over 1000 t and 35-40 smaller buyers of cotton seed.	About \$8 million	5 full time
Cotton gin and marketing 2	More than 25 years	Crucial (more than 90% of income), about 35 growers serviced.	\$2-10 million	70 full time, 100 casual from March-July in the Namoi Valley

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Table 23. Cotton growers, Gunnedah.

Grower	Time farming in the area	Scale of cotton production	Other land uses	Water allocation	Best profit in the last 5 years	Employment
Grower 1	25 or more years	506 ha (irrigated) at 9.2 bales/ha or 1.6 bales/ML, also 200 ha dryland.	Wheat, canola and cattle	1520 ML General Security, 1600 ground water entitlement and 8 ML high security (2870 ML used last season)	Over \$1 million	5 full time, 2 casual and 5 contractors
Grower 2	15 to 25 years	282 ha at 12 bales/ha or 1.9 bales/ML	Cattle, wheat, barley, chickpeas, dryland cotton	642 ML groundwater entitlement and 2400 unregulated (1700 ML used last season)	\$500,000-\$749,000	2 full time, 2 full time contractors, 7 casual
Grower 3	25 or more years	464 ha at 10-12 bales/ha or 3.3 bales/ML	Wheat, barley, canola, corn, sorghum, dryland cotton and faba beans.	1724 ML ground water entitlement plus 300-600 ML overland flow used every year (1400 ML used last season)	\$750,000 to \$1 million	6 full time, 1 part time and 2 casual

Note. ha=hectare; ML=mega litre

Managing change

The growers interviewed in Gunnedah had more diverse farming operations than those in St George, including cattle and growing other crops such as wheat, barley, canola, faba beans, corn and sorghum. When asked about their management actions in the last five years, the growers interviewed in Gunnedah all indicated that they had changed their irrigated production crop mix and improved the efficiency of their irrigation infrastructure. Two of the growers also said they had increased their irrigated area.

The following comments highlight how farmers managed the changing situation brought about by the recent drought:

“During the drought this farm increased non-irrigated cropping, maintained income through off-farm contracting and increased water efficiency, thus leading to an increased area of irrigated production.”

“During the drought lateral move irrigators were installed to save water.”

“Water saving for next season's cotton crop is also an important strategy and allows some forward selling each year to get a better price.”

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“This farm is planning for reduced water availability over the next five years, but the reduction of water availability is not a major threat because of the certainty of rainfall and groundwater.”

“There was no effect on the business during the recent drought because of the reliability of the area, and the high rotation of crops is for agronomic, marketing and risk management reasons.”

Water availability

Farmers were also asked to predict their actions if water availability (and its impact on cotton related businesses) was decreased or increased by 10, 25 or 50%, respectively. This question was not as crucial as in St George, because the growers saw it as less relevant to their operation; there is much higher water security around Gunnedah because of access to ground water and higher rainfall. The overall results were:

- one farmer indicated that his water availability didn't change because of the reliability of ground water and rainfall on the Liverpool Plains
- one farmer indicated that he would have to reduce labour requirements at a cut of 10% water availability
- one farmer indicated that a 10% cut in water availability would lead to reduced labour requirements, decreased plantings and changed crop mix, while a 25% reduction would lead to him leaving farming and the community.

Diversity is one of the key general resilience attributes (including business types and approaches, income sources and livelihoods, individuals, ideas and innovation). The resilience assessment found that the cotton industry feels that diversity (particularly in terms of approaches and innovations) is highest at the farm and regional scale. These answers show the diversity of business operations amongst growers and illustrate the difficulty in generalising the effects of cuts to water availability on the local economy as a whole.

Managing change in supply chain businesses

Businesses in the Gunnedah cotton supply chain were asked a similar question to farmers i.e. to predict their actions if cotton related business was decreased or increased by 10, 25 or 50%, respectively. The businesses interviewed were unlikely to take action before their cotton related business was reduced by half, and the most likely actions were to seek other business income and reduce staff. For the two ginning companies interviewed, reducing cotton business had a much more direct impact; one indicated that they would reduce staff at a decrease of 10% and one at a decrease of 25%. Both indicated that they would sell business assets and seek other business income at 25% or more reduction in cotton production.

The following comments highlight how business operators in Gunnedah managed the changing situation brought about by the recent drought.

“Irrigation supplies and infrastructure is a growth area, with growers looking to increase their efficiency all the time. The drought did not lead to a change in business, and it focused attention on water availability.”

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“Changing cotton production had a direct impact on this gin during the drought, which halved its workforce from 2004 until the upturn in the last few seasons.”

The gin also used strategies such as reducing work hours and working five days instead of seven to maintain full time staff.

“Changing cotton production is managed through decreasing casual staff, dealing in other commodities (for example, grains) and reducing capital expenditure.”

“Plants can also be “moth balled” or closed down for a finite time so that a smaller number of gins are run at full capacity.”

Conclusion

The schematic supply chain (see Figure 29, page 85) above implies a somewhat linear approach that belies the continuous adaptation that players in the chain make all through the growing season. The interviews from both study areas demonstrated how growers and downstream businesses alike will take action all through the season in anticipation of higher (or lower) activity levels. And with the fourfold and sixfold year-to-year peak to trough variances demonstrated in Figure 27 (page 83), the growers and businesses in the case study areas are very well experienced in adapting to changing circumstances.

Adaptation summary

Grower adaptation

The interviews showed that growers are used to managing the wide fluctuations in area planted and the value of their harvest. This diversity of options (given cotton is mostly grown as part of mixed farming enterprises) and diversity of response confers greater resilience on the cotton industry as a whole.

Feedback was consistent from growers interviewed that a reduction in water availability of 10% or 20% is well within their normal business parameters and they will use immediately available tools to vary the mix of farm operations and scale of planting to minimise any negative impacts on their farm businesses by reducing costs and widening income streams where possible. Adaptive measures taken were:

- increase borrowings
- sell business assets
- seek other business income
- reduce labour (and defer non-essential spending)
- decrease plantings
- change crop mix – minimal area of cotton, with balance to crops requiring less water.

Further reductions in water availability, though, have much deeper effects on operations. A 50% reduction in water availability means that growers will review the viability of the farm in that season and will consider selling assets, finding other income or employment, leaving farming and leaving the community.

In practice, cotton is an opportunistic crop so most growers move into or out of it depending on their expectations of profitability from the crop. Over the decade of the drought there is no clear sign of actual farm exits. The areas planted varied substantially through the decade,

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but by 2011 were at record levels for the two regions, indicating growers returning to cotton when they felt the time was right (see Figure 27, page 83).

Cotton Australia information suggests that most cotton growers in these two regions have other farm income than cotton, with estimates that between 60 and 70% of Upper Namoi cotton grower incomes from cotton, and 80% in St George-Dirranbandi.

Business adaptation

The interviews showed that cotton supply chain businesses are also used to harvest variability. Business owners report that they take some action if activity levels drop by up to 25%, but that the main actions involve monitoring and reducing costs by, for example:

- scaling back purchasing
- scaling back casual staff but maintaining 'permanent' staff.

As with growers, though, if activity levels drop by 50% then more drastic action follows such as active diversification into other business income, overall reductions in staff and contractors and reduced spending on other operating costs. Only those businesses directly handling farm products react faster – with cotton gins adjusting their casual employment levels to suit the scale of flow of cotton bales.

It is clear that in assessing resilience in these rural study areas, the main players in the supply chains are experienced in handling variability in agricultural activity levels, and that there is not a simple, linear relationship between planting, harvest and local flow-on spending. In particular, it is not accurate to predict flow-on spending by growers, or employment levels on farms or processing businesses, as a fixed proportion of areas under crop across a wide range of cropping areas. There is a tipping point for grower and business adaptation between 25% and 50% reductions in water availability, with practices for both groups changing significantly across this boundary.

Local and regional impacts

Agriculture is the foundation of each of the two study areas, and local farmers will no doubt continue to adapt their practices. To understand how these future adaptations will impact on their local economies, it is important to understand how agriculture is linked to the wider local economy.

The trends in cotton growing that have the most impact on the local economies in Namoi and Balonne are:

- grower numbers
- grower activity and productivity
- grower local spending and employment.

Grower numbers

While precise grower numbers are not available for the decade, the best indication of how many farmers were growing cotton can be seen in the annual hectares planted to cotton in Figure 27. In the Namoi this ranged from a low of 6,000 ha in 2003 and 2008 to 31,000 ha in 2011. In St George it ranged from 3,500 ha in 2008 to 28,000 ha in 2011.

Grower activity and productivity

Grower activity is also best measured by the areas planted to cotton in each year – a measure of the extent of local economic activity stimulated by cotton growers. Yields varied though the decade, but were typically between 8 and 9 bales/ha on average.

Grower local spending and employment

The direct impact of production on the local economies depends on the areas planted and the yield. Analysis of grower financial data (Cotton CRC 2006) shows that cotton operating costs increased steadily over the decade from 1997 to 2006 from around \$2,500/ha to around \$3,300/ha. More detailed analysis of these costs shows that the component of this spent locally was around \$2,600/ha in 2006 on inputs like machinery repairs and maintenance, motor vehicles, seed and wages. Over time, the local spend has increased slowly with inflation from around \$2,100/ha to \$2,600/ha, while decreasing in its share of operating costs from 86% to 79%. This trend indicates that the direct local spend from growers is decreasing, irrespective of planting and harvest levels.

The share of employee wages in costs has been steady at around 10% of operating costs, and there was more money spent on wages (per ha) in drought years 2003 and 2004 than in other years indicating sustained levels of on-farm activity even during these very tough years.

Overall, cotton farms employ one person per 180 ha under cotton, with the top 20% of cotton growers employing fewer people (290 ha/permanent employee).

Cotton prices are another important determinant of the impact of cotton production on local communities. The cotton price in Australia had generally been trending down over the last decade before turning up in 2008 and then showing a major spike in 2011 when it averaged \$840/bale.

As the profiles showed, measured in terms of employment or business numbers, agriculture in both communities takes up a high percentage of total activity. But how much difference does a change in agricultural activity make to the local economy?

A 2005 report into the impacts of drought 'beyond the farm gate' on non-farm businesses and communities⁸⁹ identified four types of businesses in a rural or regional community with quite different linkages to (and dependencies on) agriculture (see Figure 30).

⁸⁹ Houghton (2005) *Beyond the Farm Gate: Drought Impacts on Non-Farm Businesses and Communities* op cit

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Dependence on farmers Low High	3 rd quadrant <i>Local essentials businesses</i>	4 th quadrant <i>Local luxuries businesses</i>
	1 st quadrant <i>Bedrock businesses</i>	2 nd quadrant <i>Rural support businesses</i>
Essential Luxuries Discretionary purchases		

Source: Houghton 2005

Figure 30. A model of primary production impacts on small business.

This model proposes that the immediate sphere of influence of the farm sector is strongest on those businesses with direct supply chain links (first and second quadrants), and is weakest for businesses that supply the goods and services that keep the community going (3rd quadrant).

The Bedrock Businesses are those that rely on farmers as essential customers, and they buy goods and services even when farm production levels are low. Typical examples are the stock and station ‘seed, feed and weed’ suppliers, machinery dealers and farm maintenance providers.

The Rural Support Businesses are those that also rely on farmers as essential customers, but there is some discretion in what is bought and when, and purchases are closely aligned to production. Typical examples are crop purchase brokers/wholesalers, farm-related transport, motor vehicles, hardware and plumbing/drainage suppliers.

For the Local Essentials Businesses, farmers and farming families are important customers, but their significance is diluted as these businesses draw customers from other parts of the community as well. Typical examples of these ‘essentials’ are businesses that sell food, health care, essential services, news and local paper (but not magazines or books), some (work) clothes and real estate.

Farmers form just part of the customer base for the Local Luxuries Businesses, and the goods and services sold are seen more as luxuries that can be done without when cash is tight. Typical examples are gift shop, florist, hairdresser, non-work clothes, travel services.

Interviews conducted for the ‘beyond the farm gate’ research showed that the many farmers continued buying their core goods and services during the drought, meaning that while turnover in the bedrock businesses was lower than in good years, they were still busy. The businesses most affected by the drought were those that relied on decent production levels, and with production way down these rural support businesses had very little work. Without crops to harvest or transport, or wool to aggregate and sell there was no demand for these particular businesses. The research also found that with on-farm incomes falling very low, the Exceptional Circumstances payments for farming families had a significant

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impact in ensuring there was enough local spending to enable people to stay in the district, keep shopping locally and keep the local 'essential services' businesses going.

The different responses to low crop levels between quadrant 1 and quadrant 2 businesses was also seen in the interviews done in the case study areas for this research.

Farmers maintain the primary/fixed costs associated with producing:

*"During the drought we grew whatever cotton we had the water to grow."
"In the irrigation area our fixed costs are quite high"*

"The biggest impact on the bottom line is cotton production . . . your first and foremost focus is to have production."

But, secondary costs are reduced, affecting many businesses to some degree:

"The St George irrigation area . . . is made up of predominantly family farming operations and without the St George irrigation area, St George businesses would not have had the core, the critical mass to be able to stay in town . . . the critical mass of demand for their services and their goods is being maintained by . . . the farmers."

"In a dry year we don't replace any machinery at all."

Reflected in another comment by machinery business:

"We were greatly impacted [during the drought period]."

The study found that:

'Producer behaviour – especially financial behaviour – is a huge buffer on the flow-on impact to communities. How producers have coped with the drought has had a dramatic impact on mitigating those flow-on effects. The keys have been improved farm management practices, low interest rates, high land values, cash relief measures and, for some 10% of drought-affected broadacre farmers, use of farm management deposits.

The national figures show that the drought has had a major quantitative impact on Australia – a 46% fall in real farm incomes across the board and 0.9% knocked off GDP for 2002-03 according to Treasury⁹⁰.

There is another important factor, the role of women in regional communities has changed dramatically since the 1982 drought, and even since the 1994 drought. Many more women are actively involved in farm management, are working for wages in nearby towns, or are running their own businesses now than they were 20 or even 10 years ago. All these activities diversify farm income bases and enhance farm resilience to drought.'

⁹⁰ Lu, L. and Hedle, D. (n.d.) The impact of the 2002-03 drought on the economy and agricultural employment, by Lan Lu and David Hedle, (<http://www.treasury.gov.au/documents/817>, accessed 4 June 2004)

In summary

The drought case study demonstrates the existing adaptability in the cotton industry at the farm and regional scale to wide variations in water availability (and consequently the related variations in the cost of production) and the effect of the farm scale thresholds or tipping points.

At the farm scale many (potential) growers simply stop growing cotton when they feel it appropriate to do so. This then has a flow-on impacts on the wider regional scale. This farm scale state change is very much a regular occurrence in cotton production and is demonstrated clearly during the drought.

The case study of the Millennium drought provides practical examples of the concepts addressed in the resilience assessment and highlights the degree to which a resilience-based approach is already used although perhaps not identified as such. This is both a sign of overall industry resilience, particularly if growers in some regions will always be planting to some degree, but also of the risk associated with known thresholds (and hence vulnerability). If these states are maintained for any length of time, particularly driven by climatic extremes, cotton growers (and indeed cotton growing regions) can cease cotton production more permanently and transition to a state where a farm or region is no longer capable of cotton production.

Conclusion

Cotton production in Australia will require continuous adaptation to changing circumstances. Resilience assessments are undertaken to identify risks, opportunities and strategies in ways that are often not addressed by conventional management approaches. The Cotton Research and Development Corporation has undertaken a resilience assessment of the Australian cotton industry at multiple scales to better understand how to best adapt to change and identify critical threats and opportunities for the industry, and strategically target investment and resources.

The Australian Cotton Industry is well organised and confident in its ability to cope with change whilst also aware of facing significant challenges in the mid to long term. Some of these such as climate change, water availability thresholds, input requirements and low diversity are significant.

In the wider context, this resilience assessment of an industry as a whole is a first. The process of undertaking a resilience assessment in collaboration with stakeholders has led to a greater shared understanding of the cotton industry from a multiple-scale, farm, region and industry systems perspective. This is another important objective of resilience assessment. Working with cotton growers and industry leaders this assessment has collaboratively:

- defined focal scales
- developed timelines based on past shocks and changes
- identified key assets, inputs, outputs, drivers, dynamics and critical thresholds
- understood the status and trend of general resilience attributes
- considered cross-scale interactions.

This has developed the industry's capacity to understand the nature of this complex adaptive system. This in itself enhances the resilience of any social-ecological system⁹¹ and is a positive outcome for the future of the cotton industry.

Interventions that would strengthen the industry have been identified for both specified and general resilience based on the assessment priorities. Resilience assessments, given the complex adaptive systems they address, can never be complete. This assessment is a snapshot of the industry and its current dynamics based on the best available information and reflecting current industry perceptions. New challenges and unexpected issues will undoubtedly emerge in the future.

It is important to acknowledge this uncertainty and plan for ongoing adaptive management, evaluation and revision of both the assessment and the use of indicators. Assessment and measurement of resilience should be iterative and ongoing, in keeping with best practice⁹². It is recommended that this be done in collaboration with industry stakeholders to continue to build capacity to apply resilience thinking and manage complex adaptive systems at a range of scales.

CRDC's long-term goal is that *"the Australian cotton industry is the global leader in sustainable agriculture"* and is striving to achieve a vision of *"Differentiated, Responsible,*

⁹¹ Biggs, *et al* (2012)

⁹² Quinlan *et al* (2015)

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Tough, Successful, Respected and Capable” by 2029⁹³. This resilience assessment is another important step in supporting the cotton industry to achieve those goals through strategic effort and investment.

⁹³ Emergent Futures (2010)

References

- Aldunce, P., Berlin, R., Handmer, J. & Howden, M. (2014). Framing disaster resilience. *Disaster Prevention and Management*. 23:252-270
- Anderies M., Ryan P., Walker B. and Abel N. (2006) Crisis, loss of resilience and institutional change: a case study from south-eastern Australia. *Ecosystems* 9, 865-878.
- ANZSIC (2015) Cotton Ginning Market Research Report. ANZSIC A0521.
<http://www.ibisworld.com.au/industry/default.aspx?indid=34>
- Australian Cotton Industry Development & Delivery Team (2013) *WATERpak - A guide for irrigation management in cotton and grain farming systems*. Cotton Research and Development Corporation. Narrabri
- Balgopal, M. M., Klein, J. A., Brown, C. S., McMeeking, L. B., Morgan, J. A. and Frasier, W. M. (2014). Linking Biophysical, Socioeconomic, and Political Effects of Climate Change on Agro-Ecosystems. *Journal of Geoscience Education* 62:343
- Ban, N., Mills, M., Tam, J., Hicks, C.C., Klain, S., Stoeckl, N., Bottrill, M, C., Levine, J., Pressey, R.L., Satterfield, T., and Chan, K.M.A. (2013) A social-ecological approach to conservation planning: embedding social considerations. *Frontiers in Ecology and the Environment*, 11 4: 194-202
- Berkes, F. and Ross, H. (2013) *Community Resilience: Towards and Integrated Approach*. Society and Natural Resources 26:5-20
- Barnett, P. (2014) *Designing a Future for Australian Cotton*. Report by Barrett Consulting for Cotton Research and Development Corporation, Australia
- Bianchi, F.J.J.A., Walters, B. J., ten Hove, A. L. T., Cunningham, S. A., van der Werf, W., Douma, J. C., and Schellhorn, N. A. (2015) Early-season crop colonization by parasitoids is associated with native vegetation, but is spatially and temporally erratic. *Agriculture, Ecosystems and Environment*, 207: 10-16
- Biggs, R., Schluter, M., Biggs, D., Bohensky, E. L., BurnSilver, S., Cundill, G et al (2012) Towards principles for enhancing the resilience of ecosystem services. *Annual Review of Environment and Resources* (17)18
- Boyce Chartered Accountants (2013). *Australian Cotton Comparative Analysis 2012 Crop*. Report to Cotton Research and Development Corporation 2012
- Boyce Chartered Accountants (2014). *Australian Cotton Comparative Analysis 2013 Crop*. Report to Cotton Research and Development Corporation
- Boyce Chartered Accountants (2015). *Australian Cotton Comparative Analysis 2014 Crop*. Report to Cotton Research and Development Corporation
- Brandon-Jones, E., Squire, B., Autry, C. W. and Peterson, K. J. (2014). A Contingent Resource – Based Perspective of Supply Chain Management. *Journal of Supply Chain Management* 50:55-73
- Cabell, J. F. & Oelofse, M. (2012). An Indicator Framework for Assessing Agroecosystem Resilience. *Ecology and Society* 17:18
- Carpenter, S. R., Westley, F & Turner, M. G (2005) Surrogates for Resilience of Social–Ecological Systems. *Ecosystems* 8:941-944
- Carpenter, S., Walker, B., Anderies, J. M., and Abel, N. (2001). From Metaphor to Measurement: Resilience of What to What? *Ecosystems* 4: 765–781
- Carpenter, S.R. (2003). *Regime shifts in lake ecosystems: pattern and variation*. Ecology Institute, Oldendorf/Luhe, Germany
- Chen, G. and Bailie, C. (2007) *Development of Energy/Calc – A Tool to Assess Cotton On-Farm Energy Uses*. National Centre for Engineering in Agricultural Production 1002565/1, USQ, Toowoomba
- Cork, S. (Ed.). (2009). *Brighter prospects: Enhancing the resilience of Australia*. Canberra: Australia 21

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

- Cote, M. & Nightingale, A. J. (2012). Resilience thinking meets social theory: Situating social change in socio-ecological systems (SES) research. *Progress in Human Geography* 36: 475-489
- Cotton Australia & Cotton Research and Development Corporation (2014) *Australian Grown Cotton Sustainability Report 2014*. Cotton Australia & Cotton Research and Development Corporation
<http://www.crdc.com.au/sites/default/files/pdf/CCC14003%20Sustainability%20Report%20LOW%20RES%200.PDF>
- Cotton Info Team (2013) *Cotton Pest Management Guide 2013-14*. Cotton Info Team
- Cotton Info Team (2014) *Australian Cotton Production Manual 2014*. Cotton Info Team
- Cotton Info Team (2014) *Cotton Pest Management Guide 2014-15*. Cotton Info Team
- Cotton Info Team (2015) *Australian Cotton Production Manual 2015*. Cotton Info Team
- Cotton Info Team (2015) *Cotton Pest Management Guide 2015-16*. Cotton Info Team
- Cotton Research and Development and Corporation (2013) *Cotton Futures Forum*. CRDC, Narrabri
- Cotton Research and Development Corporation (2013) *Strategic R & D Plan 2013 – 2018*. CRDC, Narrabri
- Cotton Research and Development Corporation (2014) *17th Annual Australian Cotton Conference: Conference papers and e-summaries*. CRDC, Narrabri
- Cretney, R. (2014). Resilience for Whom? Emerging Critical Geographies of Socio-ecological Resilience. *Geography Compass* 8:627-640
- Cumming, G. S. (2011). Spatial resilience: integrating landscape ecology, resilience, and sustainability. *Landscape ecology* 26:899-909
- Dairy Australia (undated) A report on the findings of phase one of the project 'Enhancing the resilience of dairy farm businesses' (Dairy Australia Project UM12272)
- Danaher, T., Horn, G., Burley, H., Higgins, D. and Sparke, G. (2012) *Namoi Catchment Ground Cover Assessment – Determining Groundcover at the Catchment and Sub-catchment Scale*. Report prepared for Namoi Catchment Management Authority
- Deppish, S. & Hasibovic, S. (2013). Social-ecological resilience thinking as a bridging concept in transdisciplinary research on climate change adaptation, *Natural Hazards* 67:117-127
- Derissen, S., Quaas, M., and Baumgartner, S. (2011). The relationship between resilience and sustainability of ecological-economic systems. *Ecological Economics* 70 (6), 1121-1128
- Deshingkar, P. (2012). Environmental risk, resilience and migration: implications for natural resource management and agriculture. *Environmental Research Letters* 7:015603
- Dwiartama, A. & Rosin, C. (2014). Exploring agency beyond humans: the compatibility of Actor-Network Theory (ANT) and resilience thinking. *Ecology and Society* 19
- Ecological (2014) *Construction of a Vegetation Map for the North West Local Land Services Region. Extant and Pre-European Distribution of Regional Vegetation Communities*. Prepared for North West Local Land Services
- Ecological Australia (2014) *Potential for Growth in the Australian Cotton Industry. Volume 1: Research and Findings*. Prepared for the Cotton Research and Development Corporation
- Ecological (2015) *Assessment of Carbon Sequestration Potential for the North West Local Land Services (NWLLS) Region*. Prepared for North West Local Land Services
- Ecological (2015) *Development of a Biodiversity Prioritisation Plan for the North West LLS Region*. Report prepared for North West Local Land Services
- Ecological (2015) *Invasive Species Prioritisation and Implementation Framework*. North West Local Land Services. Report prepared for North West Local Land Services

- Ecosure (2015) *Ecological Values and Condition of the Travelling Stock Routes in the North West Local Land Services Region*. Report prepared for North West Local Land Services
- Emergent Futures (2010) Cotton Industry Vision 2029. Report prepared for CRDC
- Foley, J.P., Sandell, G. R., Szabo, P. M., Scobie, M. and Baillie, C. P. (2015). *Improving energy efficiency on irrigated Australian cotton farms. Benchmarking report*. NCEA Publication 1005371/1. p 7
- Folke, C. (2006). Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change*, 16(3), 253-267
- Folke, C. (2007). Social-ecological systems and adaptive governance of the commons. *Ecological Research*, 22(1), 14-15
- Folke, C. (2010). How resilient are ecosystems to global environmental change? *Sustainability Science*, 5(2), 151-154
- Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society*, 15(4), 20
- Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., & Walker, B. (2002). Resilience and sustainable development: Building adaptive capacity in a world of transformations. *AMBIO: A Journal of the Human Environment*, 31(5), 437-440
- Frazier, T. G., Thompson, C. M and Dezzani, R. J. (2014) *A framework for the development of the SERV model: A Spatially Explicit Resilience-Vulnerability model* Applied Geography 51, 158-172
- Frederik J.W. van Oudenhoven, Dunja Mijatović, Pablo B. Eyzaguirre, (2011) Social-ecological indicators of resilience in agrarian and natural landscapes. *Management of Environmental Quality: An International Journal*, 22(2):154 - 173
- Gibbons, P. (2009). Where would you put your conservation dollar? *Decision Point*, 30, 8-9
- Glover, J. (2012). Rural resilience through continued learning and innovation. *Local Economy: The Journal of the Local Economy Policy Unit* 27:355-372
- Goerner, S. J., Lietaer, B. and Ulanowicz, R. E. (2009). Quantifying economic sustainability: Implications for free-enterprise theory, policy and practice. *Ecological Economics* 69:76-81
- Grigg, N., Abel, N., O'Connell, D., Walker, B. (2015). Resilience assessment desktop case studies in Thailand and Niger. CSIRO, Australia
- Gunderson, L. H., and C. S. Holling. (2002). *Panarchy: understanding transformations in human and natural systems*. Island, Washington, D.C., USA
- Han, T. and Chung, J. (2014). Korean Consumers' Motivations and Perceived Risks Towards the Purchase of Organic Cotton Apparel. *Clothing and Textiles Research Journal* 32:235-250
- Heywood, P. and Turpin, S. (2013). Variations in Soil Carbon Stocks with Texture and Previous Landuse in North-Western NSW, Australia. *Sustainable Agriculture Research* 2:124
- Hinkel, J (2011) Indicators of vulnerability and adaptive capacity: Towards a clarification of the science-policy interface. *Global Environmental Change*. 21:198-208
- Hodgson J. A., Thomas, C. D., Wintle, B. A., and Moilanen, A. (2009). Climate Change, connectivity and conservation decision making: back to basics. *Journal of Applied Ecology*, 46: 964-969
- Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* 4:1-23
- Holling, C. S. (2004). From complex regions to complex worlds. *Ecology and Society* 9(1): 11.

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

- Houghton, K. (2005). *Beyond the Farm Gate: Drought Impacts on Non-Farm Businesses and Communities* by Dr Kim Houghton for Department of Transport and Regional Services (DOTARS)
- Hunt, W., Vanclay, F., Birch, C., Coutts, J., Flittner, N. and Williams, B. (2011). Agricultural extension: Building capacity and resilience in rural industries and communities. *Rural Society* 20:112-127
- Inovact Consulting (2012) *Australian Cotton Industry: Third Environmental Assessment*. Report prepared for Cotton Research and Development Corporation
- Instinct and Reason (2012). *Adaptive Capacity and Sustainable Communities – Main Study*. Report prepared for The Australian National University
- James, C. D. & Saunders, D. A., (2001). *A framework for terrestrial biodiversity targets in the Murray-Darling Basin*. Sustainable Ecosystems and Murray-Darling Basin Commission, Canberra
- Janssen, M. A., Ö. Bodin, J. M. Anderies, T. Elmqvist, H. Ernstson, R. R. J. McAllister, P. Olsson, and P. Ryan. (2006). Towards a network perspective on the resilience of social-ecological systems. *Ecology and Society* 11(1): 15. [online] URL: <http://www.ecologyandsociety.org/vol11/iss1/art15/>
- Johnson, F. A., Williams, K. B. & Nichols, J. D. (2013). Resilience Thinking and a Decision-Analytic Approach to Conservation: Strange Bedfellows or Essential Partners? *Ecology and Society* 18:27
- Kahn, G. A., Bakhsh, A., Ghazanfar, M., Riazuddin, S. and Husnain, T. (2013). Insect resistance and field evaluation studies of transgenic cotton lines harbouring insecticidal gene. *Advances in Environmental Biology* 4022
- Kotey, B. (2014). Small business innovation in the hostile environment of Australia's drought stricken rural communities. *Australasian Journal of Regional Studies* 20:325
- Kotey, B., P., Tony Sorensen, T. & Ron Reavell, R. (2011). *Socio-Economic and Environmental Changes Affecting Cotton Catchment Communities, First Report prepared for the Cotton Catchment Communities CRC for the Project: Innovative Regional Businesses and Options for Economic Growth in Cotton Communities, Project No: 3.02.03*, Accessed: <http://www.cottoncrc.org.au/industry/Publications/Communities>
- Lansing, J. S. (2003). Complex Adaptive Systems, *Annual Review of Anthropology* 32: 183-204.
- Levin, S. A. (1998). Ecosystems and the biosphere as complex adaptive systems. *Ecosystems* 1:431–436.
- Local Land Services (2015). *Climate Change in the North West Local Land Services Region: An Addendum for the Transitional Regional NRM Plan for the North West LLS Region*. North West Local Land Services
- Love, S., Sharma, M., Boxelaar, L. and Paine, Mark, (2007) *Enhancing the resilience of dairy farm businesses. Final Report*. (Dairy Australia Project UM12272).
- Love, S., Sharma, M., Boxelaar, L. and Paine, Mark, (2009) *The social dimensions of resilience in the dairy industry in Australia*
- Lu, L. and Hedle, D. (no date.) *The impact of the 2002-03 drought on the economy and agricultural employment*, by Lan Lu and David Hedle, (<http://www.treasury.gov.au/documents/817>, accessed 4 June 2004)
- Maani, K (2013), *Decision-making for climate change adaptation: A systems thinking approach*, National Climate Change Adaptation Research Facility, Gold Coast
- Maclean, K., Cuthill, M. and Ross, H. (2013) Six attributes of Social Resilience. *Journal of Environmental Planning and Management*. DOI: 10.1080/09640568.2013.763774
- MacLeod, G., Bristow, G. & Healy, A. (2014). Regional resilience: an agency perspective. *Regional Studies* 48:923

- Mannion, A. M. and Morse, S. (2012). Biotechnology in agriculture: Agronomic and environmental considerations and reflections based on 15 years of GM crops. *Progress in Physical Geography* 36:747-763
- Marshall, G. R. (2013) Transaction costs, collective action and adaptation in managing complex social-ecological systems. *Ecological Economics*. 88 (2013) 185-194
- Marshall, N. A., Fenton, D. M., Marshall, P. A. and Sutton, S. G. (2007). How Resource Dependency Can Influence Social Resilience within a Primary Resource Industry. *Rural Sociology* 72:359-390
- Marshall, N. A., Gordon, I. J. and Ash, A. J. (2011). The reluctance of resource-users to adopt seasonal climate forecasts to enhance resilience to climate change variability on the rangelands. *Climate Change* 107:511-529
- Meadows, D. (1999) *Leverage Points. Places to intervene in a system*. The Sustainability Institute, Hartland, VT.
- Mitchell M., Griffith R., Ryan P., Walkerden G., Walker B. and Brown V. (2013) Applying resilience thinking to natural resource management through a 'planning-by-doing' framework. *Society and Natural Resources*
- Moench, M. (2014). Experiences applying the climate change resilience framework: linking theory with practice. *Development in Practice* 24: 447-464
- Murray-Darling Basin Authority (2010), Lower Balonne Community Profile, in *Appendix C of The Guide to the Proposed Basin Plan*, Murray-Darling Basin Authority, Canberra
- Namoi CMA (2013). *Namoi Catchment Management Plan 2013 Update*. Namoi Catchment Management Authority, Gunnedah
- National Centre for Engineering in Agriculture (2015) *Energy Efficiency on Irrigated Australian Cotton Farms* University of Southern, Queensland, Toowoomba
- Niche Environment and Heritage (2015) *Biodiversity assets of the NWLLS. GIS Landscape Ecology and Species Distribution Modelling*. Report prepared for North West Local Land Services
- NSW Environment and Protection Authority (EPA) (2012) *NSW State of the Environment Report 2012*. EPA <https://www.epa.nsw.gov.au/soe/>
- O'Connell, D., Walker, B., Abel, N., Grigg, N. (2015) *The Resilience, Adaptation and Transformation Assessment Framework: from theory to application*. CSIRO, Australia
- Powell, J. and Scott, F. (2011), A Representative Irrigated Farming System in the Lower Namoi Valley of NSW: An Economic Analysis. *Economic Research Report No. 46*, Industry & Investment NSW, Narrabri
- Power, B. D. Rodriguez, P. deVoil, G. Harris, J. Payero (2011). A multi-field bio-economic model of irrigated grain–cotton farming systems, *Field Crops Research* 124 (2011) 171–179
- Prior T., Asker, S. & R. Plant (2011) *Australian Cotton Futures: Final Forum Report*. Institute for Sustainable Futures, University of Technology, Sydney for the Cotton Catchment Communities CRC. December 2011
- Quaranta, G. and Salvia, R. (2014). An Index to Measure Rural Diversity in the Light of Rural Resilience and Rural Development Debate. *European Countryside* 6:161-178
- Quinlan, A. E., Berbes-Blazquez, M., Haider, L. J., and Peterson, G. D. (2015). Measuring and Assessing resilience: broadening understanding through multiple disciplinary perspectives. *Journal of Applied Ecology*. doi: 10.1111/1365-2664.12550
- Rammel, C., S. Stagl, and H. Wilfing. (2007). Managing complex adaptive systems — a co-evolutionary perspective on natural resource management. *Ecological Economics* 63(1):9-21
- Redman, C. L. (2014). Should sustainability and resilience be combined or remain distinct pursuits? *Ecology and Society* 19:1
- Reid, R., and Botterill, L. C. (2013) The Multiple Meanings of 'Resilience': An Overview of

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

- the Literature. *Australian Journal of Public Administration* 72(1):31-40
- Reller and Gerstenberg, (1997) http://everest.physik.uni-augsburg.de/chemie/forschung/wiss_beitraege/pdf/weisses_gold_wohin.pdf
- Resilience Alliance (RA) (2007). *Assessing resilience in social–ecological systems: workbook for practitioners*. Version 1.0.
- Resilience Alliance (2010). *Assessing resilience in social-ecological systems: Workbook for practitioners*. Version 2.0.
- Rist, L., Felton, A., Nystrom, M., Troell, M., Sponseller, R. A., Bengtsson, J., Osterblom, H., Lindborg, R., Tidaker, P., Angeler, D. G. Milstad, R. and Moen, J. (2014). Applying resilience thinking to production ecosystems. *Ecosphere* 5(6): 73
- Rodriguez, D., de Voil, P., Power, B., Cox, H., Crimp, S. and Meinke, H. (2011). The intrinsic plasticity of farm businesses and their resilience to change. An Australian example. *Field Crops Research* 124:157-170
- Roth, G (2010) *Economic, Environmental and Social Sustainability Indicators of the Australian Cotton Industry*. Cotton Research and Development Corporation, University of New England & Cotton Catchment Communities Cooperative Research Centre
- Roth, G. (2013) *Cotton Growing Practices 2013. Findings of CRDC's survey of cotton growers*. Roth Rural report for CRDC
- Ryan, P., (2014) *Resilience in practice*. (unpublished working paper), Australian Resilience Centre, Victoria.
- Sandhu, H. S. and Crossman, N. D. (2012). Ecosystem services and Australian agricultural enterprises. *Ecological economics* 74:19-26
- Scheffer, M., S. R. Carpenter, J. A. Foley, C. Folke, and B. Walker (2001). Catastrophic shifts in ecosystems. *Nature* 413:591–596.
- Schellhorn, N. A. (no date) *Pest suppressive landscapes: Understanding Habitat Function*. CSIRO
- Scott, M. (2013). Resilience: A Conceptual Lens for Rural Studies? *Geography Compass* 7: 597-610
- Scott, P. S. and Scholten, K. (2014). Mitigation processes: antecedents for building supply chain resilience. *Supply chain management* 19:211-228
- Sellberg (2014) Resilience in practice for strategic planning at Municipal Level. *Resilience 2014. Resilience and Development: Mobilizing for Transformation*. Montpellier
- Sinclair, K., Curtis, A., Mendham, E., & Mitchell, M. (2014). Can resilience thinking provide useful insights into those examining efforts to transform contemporary agriculture? *Agriculture and Human Values* 31: 371-384
- Smith, P., Foley, J., Priest, S., Bray, S., Montgomery, J., Wigginton, D., Schultz, J., and Van Niekerk, R (2014) *A review of centre pivot and lateral move installations in the Australian cotton industry*. NSW DPI
- State of the Environment 2011 Committee (2011). *Australia state of the environment 2011*. Canberra, DSEWPoC
- Steffen, W., Sims, J., Walcott, J. and Laughlin, G. (2011). Australian agriculture: coping with dangerous climate change. *Regional Environmental Change* 11:205-214
- Strategic Economic Solutions and Bugseye (2014). *North West Local Land Services General Resilience Attributes*. Compilation prepared for NWLLS.
- Strategic Economic Solutions and Bugseye (2014) *NWLLS Region Socio-Economic Profiles*. Compilation prepared for North West Local Land Services.
- Streck, H. J. (2014). Herbicide Resistance – what have we learned from other disciplines? *Journal of Chemical Biology* 7:129-132
- Strunz, S. (2012). Is conceptual vagueness an asset? Arguments from philosophy of science applied to the concept of resilience. *Ecological Economics* 76:112-118

- University of Natural Resource and Applied Life Science (2014). Findings from University of Natural Resources and Applied Life Science Update Understanding of Framing (Resilience and why it matters for farm management). *Agriculture Week*. 95
- van Oudenhoven, F. J. W., Mijatovic, D. and Eyzaguirre P. B. (2011). Social-ecological indicators of resilience in agrarian and natural landscapes. *Management of Environmental Quality: An International Journal* 22:154-173
- Walker, B. H., & Salt, D. (2006). *Resilience thinking: Sustaining ecosystems and people in a changing world*. Washington, DC: Island Press
- Walker, B. H., Abel, N., Anderies, J. M., & Ryan, P. (2009). Resilience, adaptability, and transformability in the Goulburn-Broken Catchment, Australia. *Ecology and Society*, 14(1), 12
- Walker, B. H., Anderies, J. M., Kinzig, A. P., & Ryan, P. (2006). Exploring resilience in social-ecological systems through comparative studies and theory development: Introduction to the special issue. *Ecology and Society*, 11(1)
- Walker, B. H., Carpenter, S. R., Anderies, J. M., Abel, N., Cumming, G. S., and Janssen, M. (2002). Resilience management in social-ecological systems: A working hypothesis for a participatory approach. *Conservation Ecology*, 6(1), 14
- Walker, B. H., Holling, C. S., Carpenter, S. R., & Kinzig, A. P. (2004). Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society*, 9(2), 5
- Walker, B. L., Perason, M., Harris, K. G., Maler, C. Z., Li, R., Biggs, and Baynes, T. (2010). Incorporating resilience in the assessment of inclusive wealth: an example from South East Australia. *Environmental and Resource Economics* 45:183-202
- Walklate, S., McGarry, R. & Mythen, G (2014). Searching for resilience: A conceptual excavation. *Armed Forces and Society* 40: 408-427
- Walton, A. M., McCrea, R., Leonard, R. and Williams, R. (2013). Resilience in a Changing Community Landscape of Coal Seam Gas: Chinchilla in Southern Queensland. *Journal of Economic and Social Policy* 15:0_1
- Welsh, M. (2014). Resilience and responsibility: governing uncertainty in a complex world. *The Geographical Journal* 180: 15-26
- Whitten, S. M., Hertzler, G. & Strunz, S. (2011). How real options and ecological resilience thinking can assist in environmental risk management. *Journal of Risk Research* 1-16

Appendix 1. Overview of resilience

Origins of resilience

Resilience is a widely used concept across a range of fields, from engineering, psychology and ecology⁹⁴.

The concept of ecological resilience first emerged in Canadian forestry management during the 1960s when forests were threatened by the Spruce Bud Worm, a naturally occurring pest⁹⁵. Despite one of the largest aerial spraying operations in history to control the pest, outbreaks continued to increase in frequency and size with millions of hectares being impacted annually. This had major economic consequences for the forest industry.

Ecologists, particularly Holling, recognised the relationship between the disrupted ecology of the system, forestry management, budworm control methods and the frequency and size of outbreaks. In a seminal publication, Holling⁹⁶ documented the seemingly counterintuitive insight that it was bud worm control that was exacerbating the problem. By disrupting the complex ecological dynamics that had allowed the forest ecosystem to cope with small irregular outbreaks of bud worm, managers had inadvertently increased the size, frequency and severity of outbreaks, locking them into expensive and damaging broad scale spraying. Holling used the term *resilience* (from the Latin *resilire* to recoil or rebound) to describe the natural capacity of the forest system to recover following an outbreak.

Controlling bud worm, as well as other forestry practices, was reducing the capacity of the forest ecosystem to recover, making it more susceptible to larger and more severe outbreaks, i.e. its *resilience* was being lowered. Hollings observed the potential for the system to exist in different states noting the dynamics pushed the system from one state (where bud worm was a naturally occurring pest, outbreaks were small, less severe and kept in check) to another state (where bud worm outbreaks were frequent, extensive and severe) depending on how the system was managed⁹⁷.

Key terms and concepts

Resilience is used in both popular and scientific contexts. For this project, we use the definition as it applies to social, economic and environmental systems (or social-ecological systems) and the science of understanding their dynamics and evolution through time⁹⁸.

Walker *et al.* define resilience as:

*‘...the capacity of a system to absorb disturbance and re-organise while undergoing change so as to retain a similar structure, function, identity and feedbacks.’*⁹⁹

⁹⁴ Walker, B. H., & Salt, D. (2006). *Resilience thinking: Sustaining ecosystems and people in a changing world*. Washington, DC: Island Press.

⁹⁵ Folke, C. (2007). Social-ecological systems and adaptive governance of the commons. *Ecological Research*, 22(1), 14-15

⁹⁶ Holling, C. S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* 4:1-23

⁹⁷ Holling, C. S. 1973

Walker, B. H., & Salt, D. (2006).

⁹⁸ Folke, C. (2006). Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change*, 16(3), 253-267

⁹⁹ Walker, B. H., Holling, C. S., Carpenter, S. R., & Kinzig, A. P. (2004). Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society*, 9(2), 5.

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

Resilience is an attribute of a system, something that can be measured and hence can be translated into an objective, such as maintaining or improving the resilience of a particular system (e.g. improving the resilience of a cotton growing business)¹⁰⁰. The resilience of a system can be measured by:

- proximity to important thresholds or tipping points beyond which the system will move to a different state or regime
- the amount of change it can undergo before shifting into a totally different configuration
- how much resistance there is to that shift¹⁰¹.

In popular use resilience is used in a normative sense, i.e. there is an implicit assumption that resilience is a positive or desirable attribute (Cork *et al.* 2008). From a more technical perspective, however, resilience is always context dependent in that we apply some 'judgment' about the resilience of a system depending on the context and what values we want or expect the system to deliver. A system can be highly resilient but very undesirable, e.g. dictatorships, poverty traps and environmental degradation¹⁰².

Specified versus general resilience

The capacity of a system to cope with disturbance varies depending on the nature of the disturbance. Resilience science recognises external and internal drivers as the 'pushing' forces that act on systems. These drivers may be slow pressures or sharp, intense 'shocks'. An important distinction is drawn between known drivers and shocks to a system and how they might impact on values from parts of the system (termed specified resilience) and resilience against unknown disturbances (termed general resilience). It is critical to manage both specified and general resilience as focusing all efforts on known shocks will inadvertently reduce the resilience of the system to unknown shocks.

Resilience thinking

Resilience thinking is an umbrella term that describes both the science and practice of resilience science, incorporating the wider set of concepts that help to conceptualise, assess and manage resilience¹⁰³.

Resilience thinking incorporates the concepts of:

1. **Social-ecological systems.** Linked systems where social, economic and ecological dynamics are tightly interwoven, constantly interacting and influencing each other¹⁰⁴.

¹⁰⁰ Carpenter, S., Walker, B., Anderies, J. M., and Abel, N. (2001). From Metaphor to Measurement: Resilience of What to What? *Ecosystems* 4: 765–781

¹⁰¹ Walker, B. H., Holling, C. S., Carpenter, S. R., & Kinzig, A. P. (2004)

Scheffer, M., S. R. Carpenter, J. A. Foley, C. Folke, and B. Walker. 2001. Catastrophic shifts in ecosystems. *Nature* 413:591–596

Folke *et al.* 2010,

Anderies *et al.* 2006

¹⁰² Walker *et al.* 2004

¹⁰³ Walker and Salt, 2006, 2010

¹⁰⁴ Rammel, C., S. Stagl, and H. Wilfing. (2007). Managing complex adaptive systems — a co-evolutionary perspective on natural resource management. *Ecological Economics* 63(1):9–21

This concept draws on complex adaptive system sciences to explain the dynamics of complex entities such as regions, industries, large organisations, cities or the human body. In all of these systems many individual components change and interact in response to drivers, both internal and external¹⁰⁵. These constant interactions cause changes in other parts of the system that are linked, creating secondary and tertiary effects (or feedbacks). These knock-on effects (or non-linear dynamics) can cause abrupt and unexpected changes in system function or outputs¹⁰⁶ and make these types of systems difficult to plan for and manage. A relevant example would be the volatility in global commodity prices, where a range of economic, social and political factors interact to create instability in prices and no single factor or cause can be identified.

2. **Thresholds and tipping points, feedbacks.** Related to the concept of social-ecological systems and complex adaptive system dynamics, the presence of thresholds or tipping points (points beyond which dynamics change significantly) within the system creates non-linear and sometimes unexpected change¹⁰⁷. Crossing a threshold or tipping point will see the system move from one set of feedbacks that keep the system in one configuration, to a new set, driving towards a new state¹⁰⁸. Thresholds might be known (e.g. the wilting point for a crop plant) or suspected (e.g. the size of an industry required for a processor to remain viable).

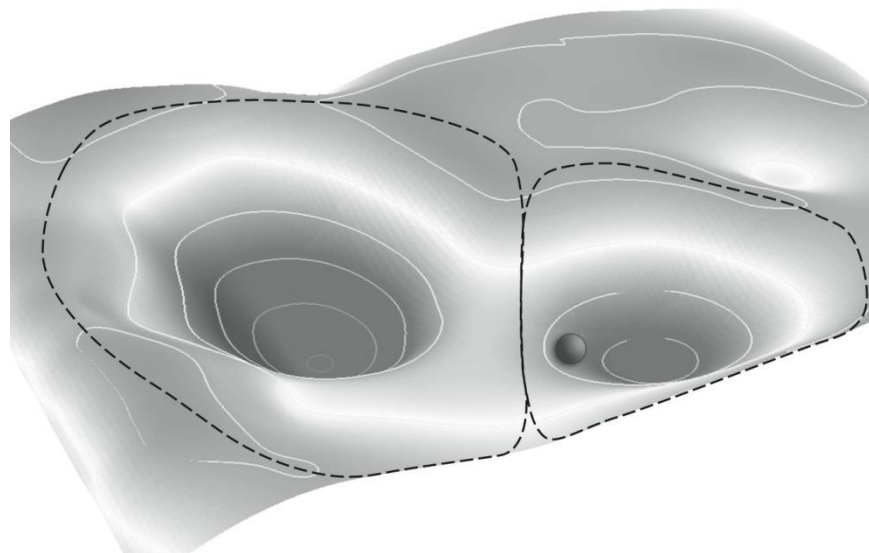


Figure 1. Alternate regimes and thresholds.

Figure 1 represents the key concept of alternate regimes and thresholds. The two 'basins' or regimes represent all the possible combinations of important factors that affect the dynamics of a system (e.g. cotton price, water availability, technology, policy setting), the ball represent the location or **state** of the system at any point in time. A system will constantly move within the same basin as the important dynamics change,

Ban, N., Mills, M., Tam, J., Hicks, C.C., Klain, S., Stoeckl, N., Bottrill, M, C., Levine, J., Pressey, R.L., Satterfield, T., and Chan, K.M.A. (2013) A social-ecological approach to conservation planning: embedding social considerations. *Frontiers in Ecology and the Environment*, 11 4: 194-202

¹⁰⁵ Levin, S. A. (1998). Ecosystems and the biosphere as complex adaptive systems. *Ecosystems* 1:431–436

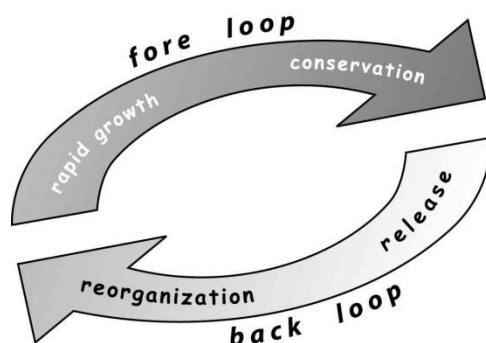
¹⁰⁶ Lansing, J. S. (2003). "Complex Adaptive Systems", *Annual Review of Anthropology* 32: 183-204

¹⁰⁷ Scheffer *et al.* 2001

¹⁰⁸ Walker *et al.* 2002

but will typically stay within the same broad regime because system feedbacks prevent the system from moving out of the basin. Drivers gradually push the system towards the lip of the basin, where shock may push the system over a threshold (by overwhelming the feedbacks keeping it in the current regime) into the next basin or the **alternate regime**. Once in the new regime, a set of new feedbacks become established keeping the system in the alternate regime, making it difficult to get back to the original regime. An example may be the gradual decline of irrigation infrastructure over time, eventually due to slow changes in commodity prices and public policy (drivers), a flood (shock) causes major damage to the infrastructure, it passes the point where the economic cost of refurbishment is too high (a threshold), the system slips into the new regime (a system without irrigation infrastructure) and the cost of establishing the system is too great (new feedbacks).

3. **Multi-scaled systems.** These systems are subsets of larger systems, all of which are linked and interact. As a result, changes at one scale influence other scales¹⁰⁹. For example, a single cotton paddock is a subset of a cotton property, which is a subset of a cotton region, which is a subset of the cotton industry. Changes of sufficient magnitude at any scale within that linked hierarchy can influence other scales.
4. **Cycles of change** (see Figure 2). As systems evolve they rapidly increase in complexity, with more connections, more capital, more rules etc. This accumulation of complexity (called the rapid growth phase) starts to slow as the system becomes more complex and resources get 'locked up' in structures (called the conservation phase)¹¹⁰. These two phases are collectively called the fore loop. As a system moves into the late fore loop, it loses flexibility and the ability to innovate or change direction (the costs of change are high) and becomes brittle or moribund. The system is now vulnerable to a shock or impact that can push it into an eventual collapse and release of connections, loss of capital stocks (release phase). Gradually the system begins to self organise, connections start to reform, new ideas and innovation enter the system (collectively this reorganisation and phase and the release phase are termed the back loop). Gradually the system will start to reorganise and move back into a growth phase. This cycle, termed the adaptive cycle, is easily recognisable in natural systems (e.g. in forest regeneration and growth following bush fire) but also occurs in social and economic systems (e.g. the growth and eventual collapse, restructure and reorganisation of a company or government agency)¹¹¹.



¹⁰⁹ Gunderson, L. H., and C. S. Holling. 2002. *Panarchy: understanding transformations in human and natural systems*. Island, Washington, D.C., USA

Holling, C. S. 2004. From complex regions to complex worlds. *Ecology and Society* 9(1): 11

¹¹⁰ Gunderson and Holling, 2002, Holling 2004

¹¹¹ Gunderson and Holling, 2002, Holling 2004

Figure 2. The adaptive cycle.

These cycles occur at different spatial and organisational scales (e.g. a farm, region and industry), and are linked and influence each other (see Figure 3). Termed *panarchy*, these linked cycles create periods of stability and slow change and periods of rapid change in systems, leading to abrupt shift in the way some systems function.

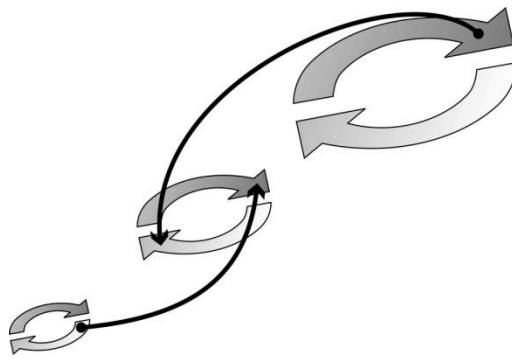


Figure 3. Linked adaptive cycles at different scales (called the panarchy).

Adaptability (adaptive capacity)

Adaptability is the combined capacity of a system to respond positively to disturbance. In social-ecological system, it refers primarily to the ability of people and organisations to respond to change, although attributes of the environment aid this capacity. Adaptability lies in the capacity to self organise, learn, and have sufficient diversity of approaches to address problems.

Transformability

Transformability is the capacity to create a fundamentally new system when ecological, economic or social (including political) conditions make the existing system untenable¹¹² is referred to as *transformability*. This capacity relies on the ability to identify alternative option for future direction of the system, the will and capacity to actively pursue that alternative future and the resources to support the shift¹¹³.

¹¹² Walker *et al.* 2006

¹¹³ Folke *et al.* 2010

Appendix 2. Assessing resilience

The process for assessing resilience has been developed by the Resilience Alliance¹¹⁴ over the last decade. It has been tested and refined in a number of different settings, although its application to specific industries has been limited to date.

The process involves six phases (see Figure 4), as follows:

Phase 1. Preparation phase. This phase involves gathering information (such as this literature review) about the systems structure, function, outputs and organisation and identifying key ‘informants’ that understand parts of the system to provide detailed insight into the critical dynamics of the system.

Phase 2. Resilience of what? This phase involves understanding and describing the system, e.g. defining the ‘focal’ scale, understanding relevant scales, documenting the values, goods, services and outputs of the system and sub-systems, and understanding the visions or aspirations (or the desired states) and values of stakeholders.

Phase 3. Resilience to what? This is the analysis phase, when data and information gathered in phase one are brought together for detailed analysis using the resilience framework to understand dynamics and focus on those issues of most concern. This phase particularly focuses on understanding critical thresholds that need to be avoided if the system is to remain in the desired state.

Phase 4. So what? This phase focuses on synthesising information to inform the development of strategies and actions to maintain or enhance the resilience of the system and determine the type or degree of change required to achieve the desired outcomes.

Phase 5. Now what? This phase focuses on turning strategy to action and setting up implementation processes to address the big issues identified, while maximising learning and adaptation opportunities.

Phase 6. Adaptive implementation. This final phase involves designing implementation of strategies and actions to both address issues identified and to refine knowledge and understanding of the system.

¹¹⁴ Resilience Alliance (RA). 2007. *Assessing resilience in social–ecological systems: workbook for practitioners*. Version 1.0.

Resilience Alliance. 2010. *Assessing resilience in social-ecological systems: Workbook for practitioners*. Version 2.0.



Figure 4. The resilience assessment process.

Appendix 3. Review of recent peer reviewed literature

International examples

Resilience as a term is used in many different ways in different sectors. Resilience thinking is used as a way of dealing with uncertainty and change in complex adaptive socio-ecological systems¹¹⁵.

The concept of resilience has been applied to a range of fields and activities - from disaster planning and preparedness, military, mental health, environmental and natural resource management, drought policy, economic performance, geography and public administration. The peer reviewed literature reveals efforts to clarify these distinctions and better understand what is meant by resilience and resilience thinking¹¹⁶. The literature reviewed also highlights the risks associated with using the term resilience without being clear about its intended meaning¹¹⁷.

Resilience thinking incorporates descriptive, evaluative and transformative elements as part of the conceptual framework¹¹⁸. The polysemous nature (i.e. having many meanings) of the term is widely acknowledged, and in some settings the less precise definitions of resilience are seen as advantageous, e.g. when undertaking cross-disciplinary initiatives and for pragmatic problem solving of complex (wicked) challenges¹¹⁹. Several more or less overlapping definitions of resilience have emerged and are relevant to natural resource managers and natural resource based industries, based on the original definition of resilience developed by Holling¹²⁰, including Walker *et al*¹²¹ and Derissen *et al*¹²².

In exploring the concept of resilience to inform responses to contemporary national security threats Walklate, McGarry and Mythen¹²³ note that resilience is a continuum and poses different (although interrelated) questions at the individual, familial, communal, institutional, regional national and global scales. In their overview of the multiple meanings of resilience in both the natural and social sciences Reid and Botterill¹²⁴, like many authors, note the risk of multiple meanings for the term resilience and emphasise the importance of defining the term clearly when using it in policy debates. Importantly, the interaction between resilience and scale is acknowledged in the literature as critical, i.e. that what may

¹¹⁵ Strunz, S. (2012). Is conceptual vagueness an asset?: arguments from philosophy of science applied to the concept of resilience. *Ecological Economics* 76:112-118; Reid, R., and Botterill, L. C. (2013) The Multiple Meanings of 'Resilience': An Overview of the Literature. *Australian Journal of Public Administration*. 72(1):31-40; Walklate, S., McGarry, R. & Mythen, G (2014). Searching for resilience: A conceptual excavation. *Armed Forces and Society* 40: 408-427; Cretney, R. (2014). Resilience for Whom? Emerging Critical Geographies of Socio-ecological Resilience. *Geography Compass* 8:627-640; Welsh, M. 2014. Resilience and responsibility: governing uncertainty in a complex world. *The Geographical Journal* 180: 15-26

¹¹⁶ Cretney 2014

¹¹⁷ Reid and Botterill 2013

¹¹⁸ Strunz 2012

¹¹⁹ Strunz 2012

¹²⁰ Holling 1973

¹²¹ Walker *et al* 2010

¹²² Derissen, S., Quaas, M., and Baumgartner, S. (2011). The relationship between resilience and sustainability of ecological-economics systems. 70(6), 1121-1128

¹²³ Walklate, McGarry and Mythen 2014

¹²⁴ Reid and Botterill 2013

confer resilience at one scale may undermine resilience at a different scale (e.g. individual versus industry).

Recently, the theory and application of resilience thinking have focused particularly on how resilience thinking can operate as a bridge and mechanism for integrating other frameworks and theories such as social change theory¹²⁵, decision-analytic approach¹²⁶, actor-network theory¹²⁷ and transdisciplinary research into climate change adaptation¹²⁸. The relationship between resilience and sustainability in particular continues to be examined as part of this area of interest¹²⁹, often, but not solely, in relation to natural resource management.

There is growing interest from business sectors in the resilience thinking framework. As key industries, such as the energy sector, recognise the increasing complexity and the drivers of change that impact on their business and operating environment, they are exploring resilience thinking as a way of managing and coping with change in uncertain times.

This interest, just as for the Australian cotton sector, has been driven by a key strategic need. In particular, the water-energy-food nexus is driving the focus on resilience for major international business/energy sectors. This same set of dynamics internationally (energy, food and fibre) have significant strategic implications for the Australian cotton industry, especially in terms of future shocks and drivers of change.

There is also a body of work on supply chain resilience in particular not only limited to natural resource based industries¹³⁰.

The international peer reviewed literature on the theory and application of resilience thinking focuses particularly on agricultural and rural settings and climate change. Climate change is featured strongly in recent literature as a key driver of change and stimulus for adaption and/ or transformation¹³¹.

The use of resilience thinking to inform approaches to agricultural and rural systems internationally has resulted in a rich area of research and investigation linked strongly to policy and practice, which is reflected in the peer reviewed literature. This includes

¹²⁵ Cote, M. & Nightingale, A. J. (2012). Resilience thinking meets social theory: Situating social change in socio-ecological systems (SES) research. *Progress in Human Geography* 36: 475-489

¹²⁶ Johnson, F. A., Williams, K. B. & Nichols, J. D. (2013). Resilience Thinking and a Decision-Analytic Approach to Conservation: Strange Bedfellows or Essential Partners? *Ecology and Society* 18:27

¹²⁷ Dwiartama, A. & Rosin, C. (2014). Exploring agency beyond humans: the compatibility of Actor-Network Theory (ANT) and resilience thinking. *Ecology and Society* 19

¹²⁸ Deppish, S. & Hasibovic, S. (2013). Social-ecological resilience thinking as a bridging concept in transdisciplinary research on climate change adaptation. *Natural Hazards* 67:117-127

¹²⁹ Sellberg (2014). Resilience in practice for strategic planning at Municipal Level. *Resilience 2014. Resilience and Development: Mobilizing for Transformation*. Montpellier; Redman, C. L. 2014. Should sustainability and resilience be combined or remain distinct pursuits? *Ecology and Society* 19:1; Namoi CMA 2013

¹³⁰ Brandon-Jones, E., Squire, B., Autry, C. W. and Peterson, K. J. (2014). A Contingent Resource – Based Perspective of Supply Chain Management. *Journal of Supply Chain Management* 50:55-73
Scott, P. S. and Scholten, K. 2014. Mitigation processes: antecedents for building supply chain resilience. *Supply chain management* 19:211-228

¹³¹ e.g. in Deppisch and Hasibovic (2013); Moench, M. (2014). Experiences applying the climate change resilience framework: linking theory with practice. *Development in Practice* 24: 447-464

investigations into resilience thinking as part of agricultural transformation¹³², as a lens for rural studies in general¹³³ and as ways to understand agro ecosystem resilience¹³⁴.

Resilience thinking has also been studied closely in relation to disaster resilience¹³⁵, managing environmental risk for social-ecological systems¹³⁶ and regional resilience¹³⁷. While these publications are not specifically focused on Australian agriculture and cotton, they provide insights and frameworks that are all relevant and provide rich insights into the context within which the industry operates.

A large body of peer reviewed literature internationally regrinds the application of resilience thinking to natural resource based industries¹³⁸. There has been particular interest in socio-ecological indicators of resilience for agricultural and natural landscapes¹³⁹. Another area of focus has been on resilience of farms¹⁴⁰, along with an interest in how resilience theory is applied to production systems in general¹⁴¹.

Recent peer reviewed publications relating to natural resource management and rural resilience focus particularly on the issues of rural diversity¹⁴², rural resilience in general¹⁴³. General resilience in natural resource industries has also been investigated in the peer

¹³² Sinclair, K., Curtis, A., Mendham, E., & Mitchell, M. (2014). Can resilience thinking provide useful insights into those examining efforts to transform contemporary agriculture? *Agriculture and Human Values* 31: 371-384

¹³³ Scott, M. (2013). Resilience: A Conceptual Lens for Rural Studies? *Geography Compass* 7: 597-610

¹³⁴ Cabell, J. F. & Oelofse, M. (2012). An Indicator Framework for Assessing Agroecosystem Resilience. *Ecology and Society* 17:18

¹³⁵ Aldunce, P., Berlin, R., Handmer, J. & Howden, M. (2014). Framing disaster resilience. *Disaster Prevention and Management*. 23:252-270

¹³⁶ Whitten, S. M., Hertzler, G. & Strunz, S. (2011). How real options and ecological resilience thinking can assist in environmental risk management. *Journal of Risk Research* 1-16

Deshingkar, P. (2012). Environmental risk, resilience and migration: implications for natural resource management and agriculture. *Environmental Research Letters* 7:015603

¹³⁷ MacLeod, G., Bristow, G. & Healy, A. (2014). Regional resilience: an agency perspective. *Regional Studies* 48:923

¹³⁸ e.g. Marshall, N. A., Fenton, D. M., Marshall, P. A. and Sutton, S. G. (2007). How Resource Dependency Can Influence Social Resilience within a Primary Resource Industry. *Rural Sociology* 72:359-390

¹³⁹ Frederik J.W. van Oudenhoven, Dunja Mijatović, Pablo B. Eyzaguirre, (2011) *Social-ecological indicators of resilience in agrarian and natural landscapes*. *Management of Environmental Quality: An International Journal*, 22(2):154 – 173; O'Connell, D., Walker, B., Abel, N., Grigg, N. (2015) *The Resilience, Adaptation and Transformation Assessment Framework: from theory to application*. CSIRO, Australia

¹⁴⁰ University of Natural Resource and Applied Life Science (2014). Findings from University of Natural Resources and Applied Life Science Update Understanding of Framing (Resilience and why it matters for farm management). *Agriculture Week*. 95

¹⁴¹ Rist, L., Felton, A., Nystrom, M., Troell, M., Sponseller, R. A., Bengtsson, J., Osterblom, H., Lindborg, R., Tidaker, P., Angeler, D. G. Milstad, R. and Moen, J. (2014). Applying resilience thinking to production ecosystems. *Ecosphere* 5(6): 73

¹⁴² Quaranta, G. and Salvia, R. (2014). An Index to Measure Rural Diversity in the Light of Rural Resilience and Rural Development Debate. *European Countryside* 6:161-178

¹⁴³ Glover, J. (2012). Rural resilience through continued learning and innovation. *Local Economy: The Journal of the Local Economy Policy Unit* 27:355-372

reviewed studies, with emphasis on general social resilience attributes rather than specified resilience¹⁴⁴.

Research into the impacts of coal seam gas (CSG) on resilience based on a Queensland region has useful insights for areas where cotton and other land uses such as CSG are competing for resources and access¹⁴⁵.

Australian examples

Using resilience thinking to better understand and manage climate change as a key driver of change has emerged in the literature, not only internationally as discussed above, but also as also a priority in an Australian context for agriculture in general¹⁴⁶ and Australian cotton production in particular¹⁴⁷.

There has also been particular research interest in economic sustainability and price risks¹⁴⁸, biotechnology¹⁴⁹ and the role of agricultural extension in resilience¹⁵⁰ as part of the broader discussions of resilience and Australian agribusiness in the peer reviewed literature.

Importantly, the issues relating to agribusiness more broadly in Australia are an important part of the context for Australian cotton – not just as part of the context and operating environment, but particularly as cotton is rarely the only crop grown, rather it is often part of a mixed farming enterprise.

The peer reviewed literature also highlights efforts to use the resilience thinking conceptual framework to better understand the resilience of the sector in relation to issues that have

¹⁴⁴ Marshall, Fenton, Marshall and Sutton (2007); Maclean, K., Cuthill, M. and Ross, H. (2013) Six attributes of Social Resilience. *Journal of Environmental Planning and Management*. DOI: 10.1080/09640568.2013.763774; Berkes, F. and Ross, H. (2013) Community Resilience: Towards and Integrated Approach. *Society and Natural Resources* 26:5-20

¹⁴⁵ Walton, A. M., McCrea, R., Leonard, R. and Williams, R. (2013). Resilience in a Changing Community Landscape of Coal Seam Gas: Chinchilla in Southern Queensland. *Journal of Economic and Social Policy* 15:0_1

¹⁴⁶ Steffen, W., Sims, J., Walcott, J. and Laughlin, G. (2011). Australian agriculture: coping with dangerous climate change. *Regional Environmental Change* 11:205-214; Balgopal, M. M., Klein, J. A., Brown, C. S., McMeeking, L. B., Morgan, J. A. and Frasier, W. M. 2014. Linking Biophysical, Socioeconomic, and Political Effects of Climate Change on Agro-Ecosystems. *Journal of Geoscience Education* 62:343; Frazier, T. G., Thompson, C. M and Dezzani, R. J. (2014) A framework for the development of the SERV model: A Spatially Explicit Resilience-Vulnerability model. *Applied Geography* 51, 158-172

¹⁴⁷ Streck, H. J. (2014). Herbicide Resistance – what have we learned from other disciplines? *Journal of Chemical Biology* 7:129-132; Marshall, Gordon and Ash 2011; Heywood, P. and Turpin, S. (2013). Variations in Soil Carbon Stocks with Texture and Previous Landuse in North-Western NSW, Australia. *Sustainable Agriculture Research* 2:124

¹⁴⁸ Goerner, S. J., Lietaer, B. and Ulanowicz, R. E. (2009). Quantifying economic sustainability: Implications for free-enterprise theory, policy and practice. *Ecological Economics* 69:76-81; Sandhu, H. S. and Crossman, N. D. (2012). Ecosystem services and Australian agricultural enterprises. *Ecological economics* 74:19-26

¹⁴⁹ Mannion, A. M. and Morse, S. (2012). Biotechnology in agriculture: Agronomic and environmental considerations and reflections based on 15 years of GM crops. *Progress in Physical Geography* 36:747-763

¹⁵⁰ Hunt, W., Vanclay, F., Birch, C., Coutts, J., Flittner, N. and Williams, B. (2011). Agricultural extension: Building capacity and resilience in rural industries and communities. *Rural Society* 20:112-127

been identified as key strategic threats to the industry such as pest resistance¹⁵¹ and herbicide resistance¹⁵², along with key drivers of change such as international buyer preferences¹⁵³ and the development of new biotechnologies such as GM¹⁵⁴.

Research into the resilience of farm businesses in Australian and the impacts of drought on that have also been published in recent years. Rodriguez *et al*¹⁵⁵ for example have looked closely at the plasticity of farming enterprises and how that increases their resilience, particularly for farming systems operating in highly variable environments. There have also been studies which investigate the nature of innovation and changes implemented by small businesses generally particularly during drought which is important context for the cotton industry¹⁵⁶.

Australian industry case studies of the application of resilience thinking

Dairy Australia explored resilience concepts to better understand and build the capacity of dairy businesses¹⁵⁷ to cope with major change. The project, undertaken by Melbourne University researchers, aimed to explore the capacity of individual dairy businesses to cope with a range of external stresses and disturbances, with the findings used to better design and target extension services at the farm scale to enhance dairy business resilience. In particular, the project strongly contrasts a resilience approach with an optimisation approach, which Love *et al*¹⁵⁸ identify as the prevailing management paradigm for the industry. The authors suggest that a resilience approach may be a more appropriate for dealing with the complex range of issues and uncertainties faced by dairy producers.

Through a literature review, workshops and case studies, the project identified attributes that may contribute to resilience, the different contexts in which different businesses are coping with change and different change dynamics within different regions.

The researchers conceptualised future change as a series of potential trajectories that any individual business could move along in response to a range of factors, without there being a single optimal pathway. Pathways could be more conservative or more radical, depending on how an individual conceptualises and responds to a range of internal and external changes and stresses. Through the development of a diagnostic framework of 11 key attributes drawn from the literature and case studies, the project was able to prompt extension teams and farmers to consider that they were able to suggest actions and approaches that may enhance the capacity of individual dairy businesses to cope with a wide range of future shocks. These attributes focus strongly on the individual farmer's

¹⁵¹ Kahn, G. A., Bakhsh, A., Ghazanfar, M., Riazuddin, S. and Husnain, T. (2013). Insect resistance and field evaluation studies of transgenic cotton lines harbouring insecticidal gene. *Advances in Environmental Biology* 4022

¹⁵² Streck 2014

¹⁵³ Han and Chung 2014

¹⁵⁴ Mannion, and Morse 2012

¹⁵⁵ Rodriguez, D., de Voil, P., Power, B., Cox, H., Crimp, S. and Meinke, H. (2011). The intrinsic plasticity of farm businesses and their resilience to change. An Australian example. *Field Crops Research* 124:157-170

¹⁵⁶ eg. Kotey 2014

¹⁵⁷ Love, S., Sharma, M., Boxelaar, L. and Paine, Mark, (2007) *Enhancing the resilience of dairy farm businesses. Final Report*. (Dairy Australia Project UM12272); Love, S., Sharma, M., Boxelaar, L. and Paine, Mark, (2009). *The social dimensions of resilience in the dairy industry in Australia*

¹⁵⁸ Love *et al* 2009

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conceptualisation of the world around them and social dimensions, with little minimal emphasis on economic or ecological dynamics. The attributes are:

1. willingness to face the reality of uncertainty
2. ability to make meaning of events in a way that builds a bridge to the future
3. ability for multi-scale thinking
4. sense of self and the extent to which it is compatible with the structural changes in agriculture
5. sense of self-efficacy
6. ability to muddle through and make decisions on the basis of imperfect knowledge
7. effectiveness of networking and social organisation
8. sense of environmental efficacy
9. sense of mutuality and collective efficacy
10. effectiveness of the institutional arrangements
11. availability of a diversity of pathways to adapt to critical issues.

There is considerable overlap between these attributes and those previously identified by a range of authors as contributing to **general resilience** (see part 1 above), i.e. the capacity to cope with unknown or unexpected events¹⁵⁹. The attributes also focus mainly at one scale, the individual, apart from attributes 9 and 10, which refer to the social and institutional structures around the individual which are recognised as important in the literature reviewed¹⁶⁰. The authors identified the need to take a multi-scale approach (as this current CRDC project does) when considering resilience to better understand the range of interactions at different scales from paddock to industry. A number of the attributes could be assessed at the family, local industry group or larger scales but it was beyond the scope of the project.

Love *et al.* suggest these attributes enhance the capacity of individuals to **recognise** threats and to **reorganise** in the face of these threats. This contrasts with the common definition of resilience (and the one used in this report), where resilience is defined as the capacity to absorb disturbance. This distinction is subtle but important. Love *et al.*'s emphasis of recognise and reorganise is more anticipatory and proactive and although this is implied in the commonly used definition, Love *et al.* provide important cues for both communication and action, something definitions containing 'absorb' do not.

Both the framework, including the 11 attributes and the revised definition of resilience provide useful insights for the CRDC resilience project.

Cotton production system and climate change

In a study on climate adaptation decision making that used the Australia cotton industry as a case study, Maani¹⁶¹ explored the utility of systems thinking for improving decision making in complex settings, such as those faced by natural resource managers adapting to climate change. The research conceptualises climate change and the need for adaptation as a *wicked problem* that is not readily solved by traditional approaches.

¹⁵⁹ Carpenter *et al.* 2013; Walker *et al.* 2014; Walker and Salt, 2009

¹⁶⁰ Marshall, G. R. (2013) *Transaction costs, collective action and adaptation in managing complex social-ecological systems*. Ecological Economics. 88(2013) 185-194

¹⁶¹ Maani, K (2013). *Decision-making for climate change adaptation: A systems thinking approach*, National Climate Change Adaptation Research Facility, Gold Coast

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Maani focuses on the strategic objective identified in the CRDC strategic R & D plan 2008-2013 to develop a more holistic understanding of the cotton industry, particularly in the face of complex and uncertain future dynamics. Through a workshop process Maani developed a systems map of the cotton industry that was intended to assist decision making about farming systems' R&D investment. The process involved:

- identifying drivers
- identifying interactions between these drivers
- developing a systems map
- analysing the system looking for key leverage points
- identifying the types of R&D required to impact or influence those key leverage points.

The outputs from the case study included a series of systems maps or influence diagrams and tables identifying different categories of R&D required to affect various leverage or intervention points in the system. The author noted the positive response from participants about the process and the new insights gained from taking a systems perspective rather than the traditional approach to R&D planning.

Resilience thinking and regional natural resource management (NRM) planning and implementation

While not focusing directly on specific industries, case studies of using resilience thinking in the NRM sector offer useful insights into the application and usefulness of the concept. Dissatisfaction with the level of on-ground progress made on many of the most serious NRM problems coupled with increasing complexity and uncertainty in the operating environment for NRM agencies and organisations have seen a rapid uptake of resilience concepts in strategic NRM planning and implementation in Australia and internationally. Half of Australia's NRM regions have now trialed the use of resilience concepts, with a number of regions fully adopting and implementing the concepts¹⁶². While the approaches taken by regions vary, the common elements are:

- adopting a systems perspective (rather than an assets or threat based approach as previous used)
- identifying drivers, thresholds, potential alternative states and feedbacks, shocks and general resilience management capacity
- identifying key leverage or interventions points (controlling variables).

Implementation is designed to test assumptions and build the evidence surrounding these intervention points¹⁶³. Engaging with key agricultural industries is an important part of the process, where information is typically developed through workshops and interviews with key stakeholders and experts.

How effective this changed planning and investment approach in NRM issues cannot be fully evaluated. The time lags and complexity of evaluating and comparing different approaches mean that an accurate comparison of a resilience approach versus other approaches is not feasible. It is clear, however, that a resilience approach provides a better 'fit' between the complexity and challenges face by NRM organisations and conceptualisation and analysis of

¹⁶² Ryan, P., (2014) Resilience in practice. (unpublished working paper), Australian Resilience Centre, Victoria.

¹⁶³ Mitchell M., Griffith R., Ryan P., Walkerden G., Walker B. and Brown V. (2013) Applying resilience thinking to natural resource management through a 'planning-by-doing' framework. Society and Natural Resources

problems than many of the other current approaches. Detailed evaluation of the application of resilience concepts¹⁶⁴ highlight a range of benefits identified by those organisations adopting the approach, including:

- new insights and increased understanding of the challenges of NRM
- new skills and capacities to think about complex problems
- new relationships and partnerships
- deeper engagement with stakeholders
- reduced complexity of the 'business'
- more targeted investment.

It is likely some of these benefits will increase over time as the capacity and skills of organisations and individuals improve with ongoing application of resilience concepts.

¹⁶⁴ Mitchell *et al.* 2013

Appendix 4. Climate change predictions for cotton growing regions

The following is a brief summary of climate change projections for core cotton growing areas in Australia from the Darling Downs in Queensland to the Central West in NSW (called Central Slopes Region) to 2030¹⁶⁵.

A more detailed investigation of the temperature and rainfall projections for the core growing regions and for current greenhouse gas emissions by 2030 shows:

- All climate models predict temperatures will get warmer although they vary in the degree of this - slightly warmer (6%) warmer (84%) and hotter (10%).
- For rainfall the pattern is mixed - 2% predict much wetter, 21% wetter, 48% no change, 25% drier, 4% much drier. The message from this is that variability is a bigger issue in the short term.
- The average winter and spring rainfall is projected with *medium confidence* to decrease. Changes in summer and autumn are possible but unclear. For the near future (2030) natural variability is projected to dominate any projected changes.
- Increased intensity of extreme rainfall events is projected, with *high confidence*.
- Average temperatures will continue to increase in all seasons (*very high confidence*).
- There is *very high confidence* in continued substantial increases in projected mean, maximum and minimum temperatures in Eastern Australia, in line with our understanding of the effect of further increases in greenhouse gas concentrations.
- For the near future (2030), the annually averaged warming across all emission scenarios is projected to be around 0.5 to 1.4 °C above the climate of 1986–2005.
- More hot days and warm spells are projected with *very high confidence*.
- Fewer frosts are projected with *high confidence*.

In the North West Local Land Services (LLS) region, which encompasses the cotton growing areas of the Namoi, Border Rivers and Gwydir river valleys, the following climate change shifts are expected:

- There will be more hot days, longer warm spells and fewer frosts.¹⁶⁶
- Average winter rainfall is likely to decrease and time spent in drought to increase.¹⁶⁷
- We can expect harsher fire-weather climate in future.¹⁶⁸
- Agriculture in general across the North West LLS region will be affected by higher temperatures, changes in rainfall patterns and in the frequency and intensity of extreme events like drought, bushfire and flood.¹⁶⁹
- Climate changes simulations suggest that there is less difference in cotton yield (non-irrigated) by projected near-future climate change compared to historical climate. However, if there is no water restriction for irrigation, a warmer climate and elevated carbon dioxide may have few positive effects on cotton yield in the major crop-growing areas in the region¹⁷⁰

¹⁶⁵ www.climatechangeinaustralia.gov.au

¹⁶⁶ Local Land Services, 2015. Climate Change in the North West Local Land Services region: An addendum for the Transitional Regional NRM Plan for the North West LLS region. p. 9

¹⁶⁷ Local Land Services, 2015. p. 10

¹⁶⁸ Local Land Services, 2015. p. 11

¹⁶⁹ Local Land Services, 2015. p. 14

¹⁷⁰ Local Land Services, 2015. p. 15

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Cotton yields in the major cotton growing regions (highlighted in red) show greater variation in yield under predicted 2030 conditions as a result (See Figure 1) for irrigated cotton. Dryland cotton also shows increased variability (Figure 2).

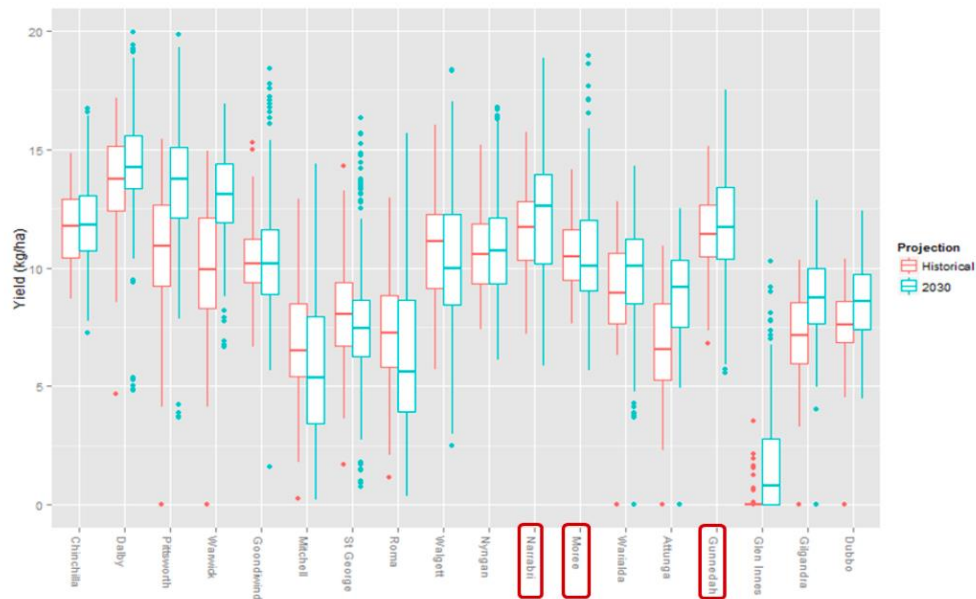


Figure 1. Effects of climate change on irrigated cotton yields across the Central Slopes region with one irrigation event.¹⁷¹

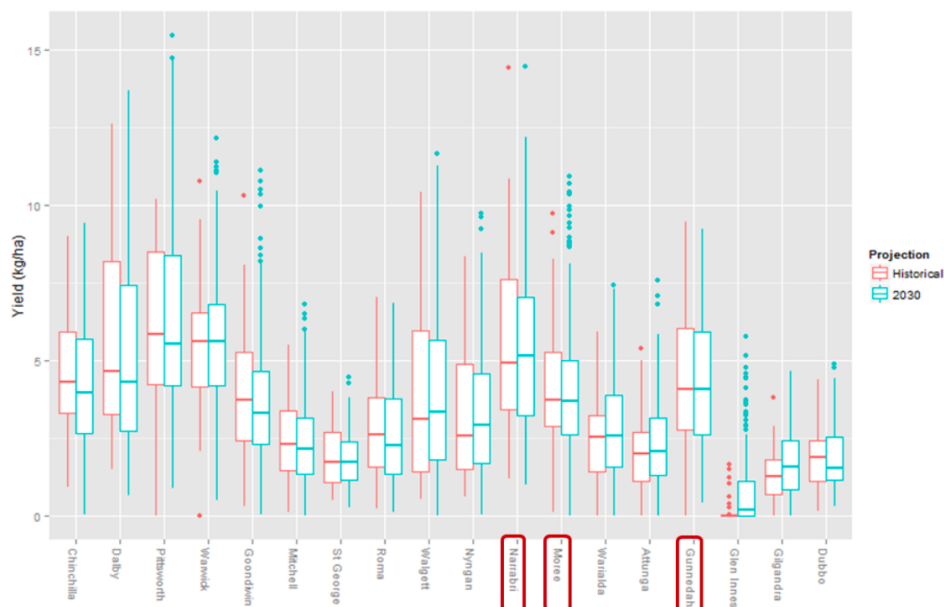


Figure 2. Climate change influence on cotton (non-irrigated) yields (kg/ha) across the Central Slopes region.¹⁷²

Given that cotton is grown as part of mixed farming enterprises it is important to note that annual pasture production is likely to be reduced¹⁷³ which has serious implications for grazing enterprises. There will also be fewer opportunities to plant crops such as wheat and

¹⁷¹ Local Land Services, 2015. p. 16

¹⁷² Local Land Services, 2015. p. 85

¹⁷³ Local Land Services, 2015. p. 17

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sorghum because temperatures will increase and there will be more periods of reduced rainfall events even though actual yield of these plants is likely to be unaffected.¹⁷⁴

¹⁷⁴ Local Land Services, 2015. p. 14

Appendix 5. Industry scale drivers and shocks

Work previously undertaken by CRDC has identified the following summary of drivers and shocks at the industry scale.¹⁷⁵

Industry level drivers of change

- terms of trade (cotton price – input costs [energy, water, fertiliser, chemicals, labour])
- global competition from other cotton producing countries and other fibres
- water quality
- water availability
- climate change
- regulation, policy and reforms, e.g. water and climate
- public attitudes and perceptions
- technology
- availability and competition for land and water
- consumer preferences.

Shocks (short term spikes in the level, intensity and/or frequency of drivers)

- climate – droughts, flooding, hail
- policy and political decision making (driven in part by public perception and opinion)
- major or new disease and pests outbreaks
- price shocks (either of input costs or commodity price)
- rapid major shifts in consumer preferences.

The literature reviewed more broadly also identified a range of drivers of change of relevance to the cotton industry. The national industry level reports identify a number of key drivers of change for the industry, which may perhaps be understood as specified shocks to the system. From the 53 responses to an online survey of industry stakeholders conducted as part of the *Vision 2029*¹⁷⁶ research process, the most important drivers of change identified were:

- water constraints/availability
- climate change and political response
- water reforms and policy
- attitudes/perceptions towards farming (political and community)
- new technology developments (including biotech)
- water use efficiency
- commodity pricing, cotton prices.

While some changes might be prepared for, others are highly uncertain as well as having potentially high impacts. In particular, respondents identified the following to be highly uncertain and likely to have significant impacts on the industry:

- competition for land between food and fibre
- marketing as a product (differentiating on quality, ethical production etc.) versus as a commodity
- quantity and variability of water supplies
- the possibility of engineered cotton replacing the need to grow cotton in soil.

Other changes, such as decreasing public funding for research and development and rising energy prices were overall perceived to be more certain, although still of high potential

¹⁷⁵ Barnett 2014

¹⁷⁶ Emergent Futures (2010)

impact. A number of other drivers and assumptions were also identified. The document also puts forward a number of scenarios, and investigating these more closely might provide insight into perceived connections between different parts of the cotton system.

The *Third Environmental Assessment*¹⁷⁷ notes the role that environmental quality, and perceptions of the industry's improvements in this area, may affect the industry's 'social license to operate'. A large proportion of growers agreed that if the industry does not further improve its environmental performance, it will result in a moderate to major threat to the industry. From the growers' perspective, the highest priority issues are irrigation water allocations, fuel efficiency and fertiliser use, although a large proportion (65%) were concerned about biodiversity and greenhouse gas emissions (49%). The 'social licence to operate' was a secondary concern, after environmental factors that affect profitability directly. Growers acknowledged that cotton had on average 'a little more' impact on the environment than other crops they grew, but viewed the industry's efforts to improve environmental performance positively. Most believed that the public and government needs to be better informed of the industry's environmental improvements.

Some of the research from the Cotton Catchment Communities CRC, which ceased in 2012, also adds to our understanding of major drivers of the industry. Their 2011 study¹⁷⁸ identifies the potential pressure points affecting production from a national perspective, but considering interactions between scales. These are grouped into four major types of factors that affect the Australian cotton industry: environmental regulation; global production system; domestic finance and the service environment.

Some interconnections between these factors are discussed (see Figure 1), e.g. within environmental regulation, water is considered to have the most significant impact on cotton production. As the report was written before the Murray-Darling Basin Plan, it suggests likely decreases in the availability of water for irrigation. Combined with expected decreases in surface water in NSW due to climate change, this was expected to significantly reduce the amount of cotton produced, thus affecting the service environment as incomes and population decline lead to smaller communities. Fluctuations in the amount of cotton production lead to increased labour costs as it becomes harder to maintain the skilled staff needed in the now high-tech industry. Low water availability (or high cost) and a low cotton price as a result of factors in the global production system, lead NSW farmers to shift to growing wheat in that season.

In some ways, this may increase the farm level resilience, although wheat prices have shifted downward when this occurred in the past. Highly fluctuating levels of production at the national scale could lead to a loss of customers, affecting Australia's quality reputation and cotton price. The report suggests low water availability in NSW could lead to increased cotton production in Queensland and WA, helping to maintain resilience of the system at the national level. While some of this increase in production in Queensland may have already occurred now that the GM ban is not in place, a more recent analysis commissioned by CRDC suggests that the opportunity for expansion of the cotton industry to new geographical areas is limited¹⁷⁹. Nonetheless, the 2011 report suggests that the cotton industry was overall confident about their ability to survive water constraints, partially because of their strong record of improving water efficiency.

¹⁷⁷ Inovact Consulting 2012

¹⁷⁸ Kotey *et al* 2011

¹⁷⁹ Ecological Australia, 2014

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A number of other drivers of note related to the global production system and domestic finance are worth mentioning. The cotton industry is affected significantly by global markets because although it has a reputation for high-medium fine cotton which attracts a premium, it is a small player globally with limited impacts on global pricing. High capital requirements increase the impacts of interest rate changes on the industry. Most competing cotton industries on the global market are highly subsidised, but the Australian industry believes a lack of subsidies, and their vulnerability globally, has improved their investment in R&D and assisted them in being a cutting-edge and adaptive industry.

Figure 3: Cotton Industry Pressure Points

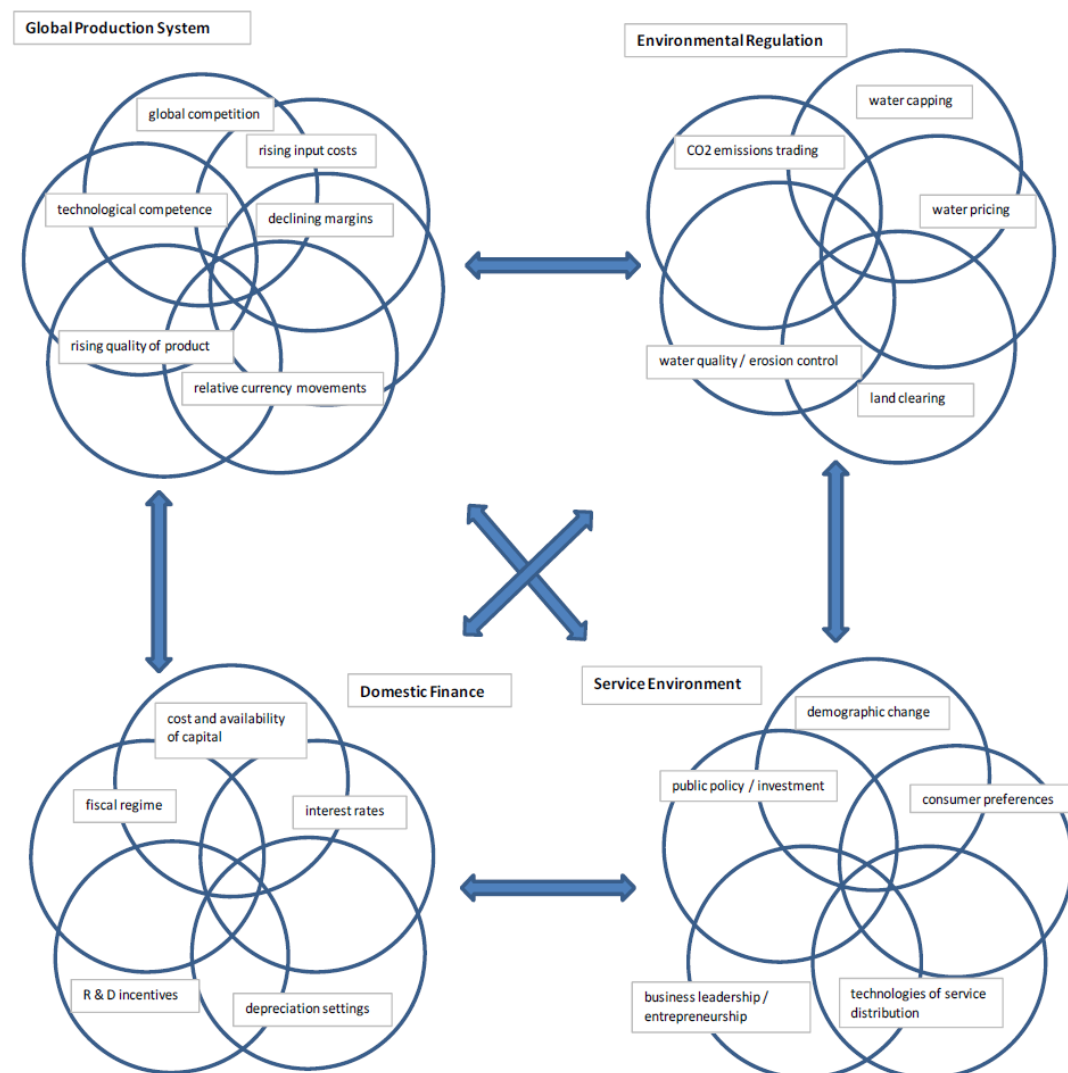


Figure 1. Cotton industry pressure points.

The *Third Environmental Assessment*¹⁸⁰ also makes some notes on the context and drivers of the cotton industry, adding some detail to our understanding of the global system. Although in 2012 Australian growers had little trouble selling their product, they were likely to face increased competition as production in India, Brazil and sub-Saharan Africa increased. Adopting Bt Cotton is one factor in these improved yields, supporting the above report's

¹⁸⁰ Inovact Consulting 2012

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suggestion that the adoption of new technologies in other nations may limit Australia's competitive edge.

Demand for fibre is expected to grow as population and wealth continue to increase. A threat to this is synthetics, but some of the industry documents have suggested that this might be minimised with increasing wealth, as many people prefer natural fibres.

The Cotton Futures Forum Delegate report, from December 2013, provides a more recent, but less detailed, understanding of changes affecting the industry at the farm, regional and national scales. These include increasing volatility in the amount of cotton produced and yields, rising input costs and skilled staff shortages. Globally, significant changes include "cotton's declining share of global fibre market, greater consumer awareness and rapidly emerging technologies". This context is also acknowledged in the Third Environmental Assessment:

"While Australia has a good reputation internationally because of the high quality of its cotton and its innovative nature in adopting new technologies and practices, its competitive edge cannot be assured without ongoing effort and investment. Water availability, input cost increases and risk management of insect and weed resistance will challenge the industry into the future. (p. 29).

Appendix 6. Australian cotton regions

Cotton production occurs between 36° South latitude and 43° North latitude and is located in tropical and subtropical regions¹⁸¹. This range covers most of Australia except South and Central Victoria and Tasmania.

In reality cotton growing is limited to areas of water availability, irrigated and rainfall moderated by adequate infrastructure and pest pressures. Currently in Australia this limits production to NSW (essentially the Murray-Darling Basin) and Queensland (central and southern).

The cotton growing regions of Australia have are subject to a wide range of climatic variability both spatially and temporally. Floods, droughts, temperature, rainfall and stored water availability all have an influence on the amount planted and the amount harvested. There is also a difference between the amounts of irrigated and dry land cotton planted both between regions and over different years.

The following diagrams illustrate the variability. The statistics are taken from the cotton year books from 2010 to 2014. There are three components to the statistics: area planted, bales produced and yield per area planted. Data on the area planted show some variability within years in the year books (the charts and text are not always consistent). Unfortunately not all regions for all years have a text description of the area planted. Therefore the figures for area planted used below may have some uncertainty but should still show overall trends. This uncertainty will flow to the average yields per hectare which have been obtained dividing the bales produced by the planted area.

The production and yield figures for the last five years for the main cotton growing regions are shown below.

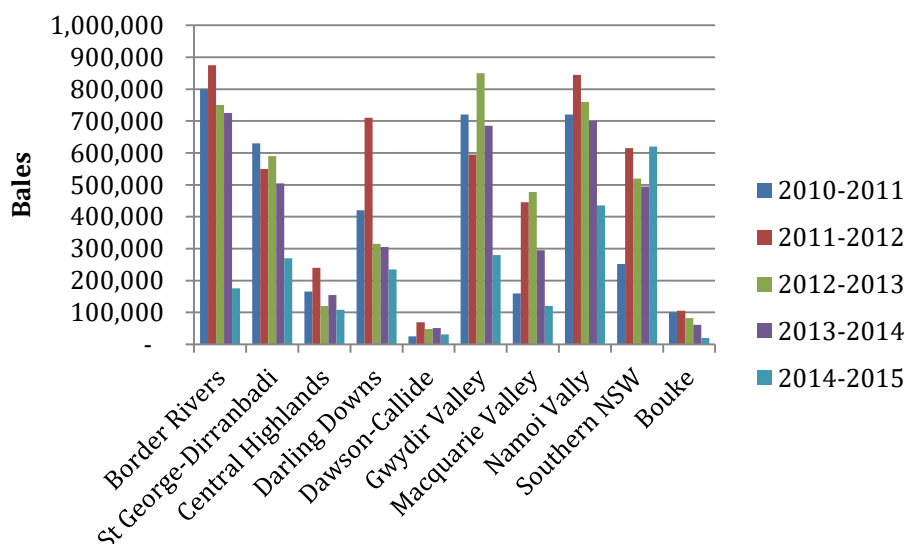


Figure 1. Cotton production by region over five recent seasons.

¹⁸¹Reller and Gerstenberg (1997) http://everest.physik.uni-augsburg.de/chemie/forschung/wiss_beitraege/pdf/weisses_gold_wohin.pdf

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The following table shows the current mix of production and the average areas grown for each of the cotton regions. St George Dirranbandi is the largest cotton growing region, and is the same scale as the Upper and Lower Namoi combined (averaging 60,000 ha grown). Cotton growing started in the lower Namoi and later the Darling Downs, with the big increase in scale occurring through the early 1970s, giving these regions plenty of experience with changing farming techniques, environmental patterns and price movements. The southern NSW region has grown rapidly to 50,000ha in just ten years.

Table 1. Cotton growing regions in Australia.

Region	Cotton grown (ha) 2014-15	Average area grown (ha)	Number of years grown
Border Rivers	12,000	40,000	1970
St George Dirranbandi	29,000	60,000	1975
Central Highlands	12,000	20,000	1970
Darling Downs	14,000	25,000	1968
Dawson-Callide	5,000	8,500	1973
Bourke	2,500	10,000	1970
Gwydir Valley	20,000	40,000	1971
Macquarie Valley	8,000	30,000	1972
Lower Namoi Valley	20,000	40,000	1961
Upper Namoi Valley	8,000	20,000	1970
Southern NSW	50,500	50,000	2005

Source: Cotton Australia unpublished data.

Figure 2 shows the contribution from each region over the last five seasons, emphasising the importance of the Namoi Valley and Border Rivers regions.

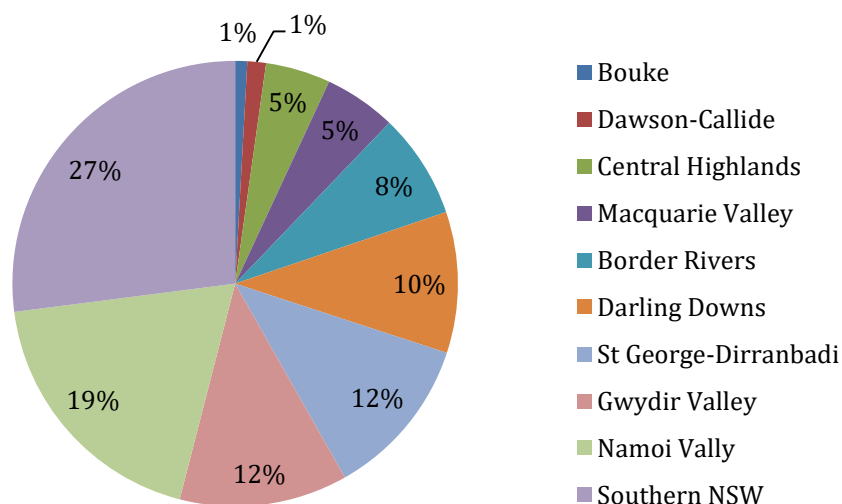


Figure 2. Proportion of total production by region over five recent seasons.

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Figure 3 shows the average yield achieved in each of the main regions from 2009 to 2014. There has been considerable variation across regions (reflecting the mix of irrigated and dryland farming) and seasons from a low of under 3 bales per hectare to a high of around 12. There is much less variation within some regions (St George Dirranbandi, for example has shown little variation around 10 bales/ha) than others (Dawson-Callide ranged from under 3 bales/ha in 2010-11 to almost 10 bales/ha in 2013-14) illustrating the different demands being placed on cotton growers in the different regions.

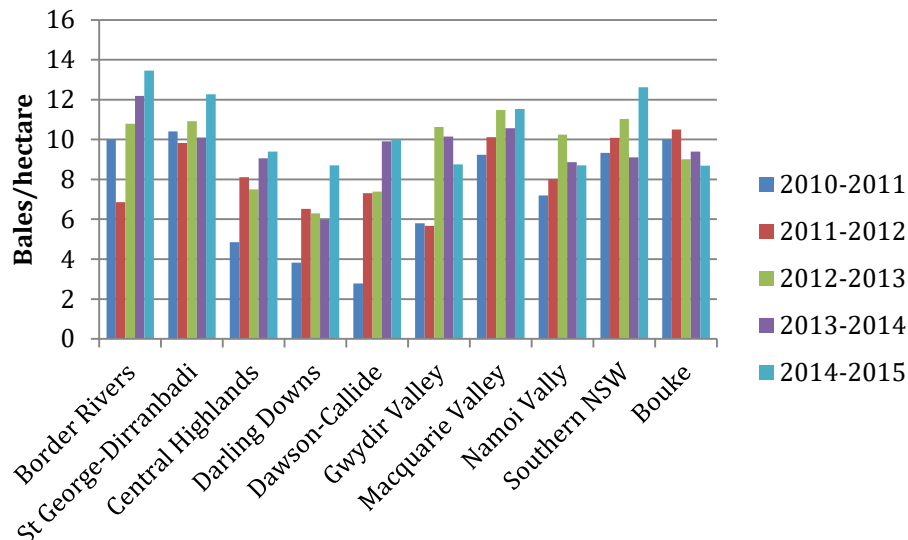


Figure 3. Cotton yield by region over five recent seasons.

Figure 4 shows the extent of regional variation over five recent seasons. While many regions averaged around 10 bales/ha, two averaged 6 or below. The average yield again reflects the mix of irrigated and dryland cotton farming. The average yield for irrigated cotton is around 10 bales per hectare, and for dryland is around 5 bales per hectare.

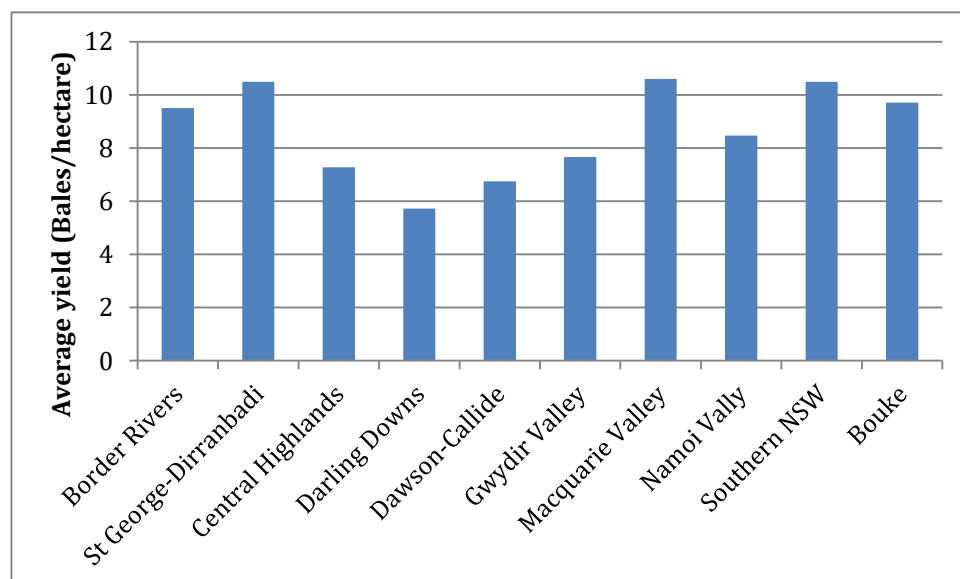


Figure 4. Average Regional yields over five recent seasons.

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

Most cotton growers have other farming activities as well, but it seems that for most cotton farmers cotton provides at least half the farm income. Most cotton growing regions are dominated by family farms, except for St George Dirranbandi and Gwydir Valley where around half farms are corporate. Only in the new southern NSW region is the share of corporate cotton farming increasing.

Table 2. Farm ownership and proportion of income represented by cotton on a regional basis.

Region	Percentage of farm income	Ownership/corporate ownership/trend	Percentage of corporate and family ownership
Border Rivers	60-70	30% corporate and steady	30% corporate 70% Family
St George Dirranbandi	80	50% corporate and steady	50% corporate 50% Family
Central Highlands	90	5% corporate and steady	5% corporate 95% Family
Darling Downs	50-60	5% corporate and steady	5% corporate 95% Family
Dawson-Callide	50-60	0% corporate and steady	0% corporate 100% Family
Bourke	90	0% Corporate and decreasing	0% corporate 100% Family
Gwydir Valley	60-70	50% corporate and steady	50% corporate 50% Family
Macquarie Valley	60-70	20% corporate and steady	20% corporate 80% Family
Lower Namoi Valley	60-70	10% corporate and steady	10% corporate 90% Family
Upper Namoi Valley	60-70	5% corporate and steady	5% corporate 95% Family
Southern NSW	60-70	25% corporate and increasing	25% corporate 75% Family

Source: Cotton Australia unpublished data

Appendix 7. Improving profitability

Annual cotton farm financial analysis by Boyce accounts has identified the main aspects of improving profitability:

The message from these figures is that better land productivity (measured by higher yields) is the major feature of the top performers. Farmers should concentrate on growing higher yield rather than searching for dramatic cost cutting measures if they wish to improve their performance significantly¹⁸².

Because of the high fixed and semi fixed costs in this industry, it is becoming increasingly important to be able to grow enough area every year to cover these costs¹⁸³

In our opinion, the main focus for growers has to be the low cost options that have the biggest impact on the bottom line. While this may be self-evident, it deserves more serious structured and documented thought by those in the industry. This study has shown that being in the top 20% is predominately driven by yield; so this is a good place to start. The central question for growers should be 'How can I improve yield as cheaply as possible?'¹⁸⁴

In terms of profitability, the threat to the high cost/high tech model is increasing technology costs. Certainly, the Bollgard licence fee has been increasing steadily (up over 170% since 2004 on a rolling 3-year average) and seed costs have increased 42%, though insecticide costs have fallen (down 72%), chipping costs have fallen (down 95%), and fertilizer costs are increasing (up 68%). Electricity, fuel and oil costs variable.

¹⁸² Boyce Chartered Accountants (2013). *Australian Cotton Comparative Analysis 2012 Crop*. Report to Cotton Research and Development Corporation p11

¹⁸³ Boyce Chartered Accountants (2013). p12

¹⁸⁴ Boyce Chartered Accountants (2014). p6

Appendix 8. Grower characteristics

The number of cotton growers with a diploma level or above qualification has risen from 30% in 1990 to 50% in 2011. These qualification levels are higher than other agricultural sectors and above the average Australian population.

There are about 6.6 people per farm (1.6 employees/100 cotton hectares, with a highly variable range across regions).

Ninety-three per cent of farmers use integrated pest management (IPM). The cotton industry has achieved an 89% reduction in insecticide use.

Cotton Australia has recently joined two international sustainability partnerships: the Cotton LEADS Program and the Better Cotton Initiative. myBMP is the Australian cotton industry's voluntary farm and environmental management system for growers to improve on-farm production. myBMP ensures that the Australian cotton industry produces economically, socially and environmentally sustainable cotton. Forty-five per cent of Australia's cotton produced is grown on farms participating in the myBMP program. [Note however the possibility of this to be mainly one sector of the cotton industry e.g. large corporate farms]¹⁸⁵

Most cotton growers have other farming activities as well. See [Appendix 10](#) for details on rates of family ownership.

¹⁸⁵Cotton Australia & Cotton Research and Development Corporation (2014) *Australian Grown Cotton Sustainability Report 2014*. Cotton Australia & Cotton Research and Development Corporation http://www.crdc.com.au/sites/default/files/pdf/CCC14003%20Sustainability%20Report_LOW%20RES_0.PDF

Appendix 9. Water use efficiency

There is some evidence to support the view identified in the work shops that there is potential for improving water use efficiency. A review¹⁸⁶ of 94 irrigation systems, comprising 44 furrow systems and 50 centre pivot or lateral move systems, reported a wide range of water application rates - from 0.6 ML/ha to 10.0 ML/ha. This was associated with a yield range of 6.5 bales per hectare to 14 bales per hectare. The data is detailed in "Table 3" copied from the review.

Table 3: The average yield and water applied to crops 2011-12.

	Furrow			CPLM		
	Sample Size	Average Yield	Average Water Applied ML/ha	Sample Size	Average Yield	Average Water Applied ML/ha
Cotton	44	10.4 b/ha (7.0-13.0)	6.2 (1.8-10.5)	50	10.1 b/ha (6.5-14.0)	4.3 (0.6-10.0)
Corn	6	13.0 t/ha (9.9-26.0)	5.02 (3.6-6.0)	10	10.3 t/ha (2.0-15.0)	4.14 (2.2-7.0)
Sorghum	5	7.2 t/ha (5.0-9.3)	2.68 (1.4-4.5)	6	8.6 t/ha (7.5-9.3)	2.2 (0.5-3.5)

Note: Figures in brackets represent the range of survey observations

While a range of water application rates is not unexpected given the diversity of farming conditions, the size of the range suggests that there is significant potential for improvement in managing irrigation. The review also noted:

"Four main observations arose from the 2011-12 survey:

- Around half the survey participants would be unable to meet a crop's peak water requirement as the Managed System Capacity was below 90% of peak crop water demand.*
- Most irrigators are now installing CPLMs on country that has been levelled or had drainage works.*
- Despite a general recognition that performance of CPLM systems should be checked at commissioning and regular intervals afterwards, only a small proportion of participants indicated that they did so.*
- While most participants are concerned about running costs of CPLM systems, about half were operating their systems above optimal pressure, potentially incurring higher running costs than necessary."*

These conclusions from the report demonstrate that there is room for improvement in the management of existing CPLAM machines in terms of both design and maintenance. In particular, given rising energy costs, irrigators have the potential to reduce costs by operating their machines correctly.

¹⁸⁶ Smith, P., Foley, J., Priest, S., Bray, S., Montgomery, J., Wigginton, D., Schultz, J., and Van Niekerk, R (2014) *A review of centre pivot and lateral move installations in the Australian cotton industry*. NSW DPI

Appendix 10. Farm income derived from cotton

Most cotton growers have other farming activities as well, but it seems that for most cotton farmers cotton provides at least half the farm income. Most cotton growing regions are dominated by family farms, except for St George Dirranbandi and Gwydir Valley where around half farms are corporate. Only in the new southern NSW region is the share of corporate cotton farming increasing.

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Bourke	90	0% Corporate and decreasing	0% corporate 100% Family
Gwydir Valley	60-70	50% corporate and steady	50% corporate 50% Family
Macquarie Valley	60-70	20% corporate and steady	20% corporate 80% Family
Lower Namoi Valley	60-70	10% corporate and steady	10% corporate 90% Family
Upper Namoi Valley	60-70	5% corporate and steady	5% corporate 95% Family
Southern NSW	60-70	25% corporate and increasing	25% corporate 75% Family

Source: Cotton Australia unpublished data

Appendix 11. Historical gross margins on NSW crops – comparing cotton with alternatives

Cotton is a highly profitable crop under many scenarios. Comparative gross margins are shown here for irrigated and dryland farming regions.

Table 1. NSW summer dryland 2012-13.

Crop	Gross margin/ha
Dryland cotton*	\$51
Dryland sunflowers	\$217
Dryland grain sorghum	\$183

Source: NSW DPI, Farm Enterprise Budget Series North West NSW

* Note this estimate at 2.7 bales/ha and \$380/bale. At 4.7 bales/ha (dryland average for last 3 years) and \$410/bale (below average of last 3 years) GM is \$935/ha.

Table 2. NSW summer irrigated 2012-13.

Crop	Gross margin/ha	Gross margin/ML
Spray irrigated Azuki beans	\$767	\$110
Surface irrigated cotton	\$1580	\$226
Surface irrigated maize	\$860	\$120
Spray irrigated mung beans	\$521	\$347
Spray irrigated navy beans	\$475	\$158
Surface irrigated sorghum	\$741	\$195
Surface irrigated soy beans	\$544	\$91
Spray irrigated lucerne	\$1032	-
Surface irrigated sunflowers	\$708	\$182

Source: NSW DPI, Farm Enterprise Budget Series Northern Zone

A comparison done by Cotton Seed Distributors in 2008 for irrigated land shows a similar range of gross margins, with cotton the highest of the five crops compared.

Table 3. Crop gross margin comparison.

	Cotton	Corn	Soybeans	Sunflowers	Sorghum
Grown ha	138	140	167	256	263
Outlay \$	\$341,304	\$229,441	\$175,663	\$221,507	\$355,843
Average yield	10.54 bale	10 t	3.5t	2.5t	9t
Return \$	\$698,402	\$447,552	\$408,333	\$471,154	\$509,211
Gross margin	\$357,098	\$218,112	\$232,670	\$249,647	\$153,637

Source: CSD Summer Crops Gross margin Analysis Sept 2008

In presenting these ‘back-of-the-envelope’ calculations the report notes that:

There are two things which stand out in this analysis. Firstly, although the area grown to cotton is the smallest amongst the commodity group it returns the most dollars to the enterprise. In a limited resource scenario the focus is on obtaining the most return from that resource, as it drives profitability.

Secondly, the rate of return on investment for cotton is similar to the other commodities at current price levels. Obviously this is going to change with commodity prices fluctuating as seasonal influences progress. However, the ratio between outlay and return is quite similar across most of the commodities within this analysis. Therefore for the same relative risk, you are returning substantially more money from a cotton system. For example, the growing costs for 138 ha of cotton are very similar to the growing costs of 263 ha of sorghum. However, the cotton system returns \$203,461 more to the farm enterprise than the increase planted area of sorghum.

Appendix 12. Cotton production input cost trends

Detailed information on income and expenses for cotton farms are provided in the annual Australian Cotton Comparative Analysis reports produced by Boyce Accounting. The data does not cover the whole industry, but a sample of irrigators, with a comparatively large average farm size (1500 ha) and 520,000 bales in 2013 (11% of harvest).

The four biggest costs total 43% of average costs per hectare and are fertiliser, fuel and oil, employee wages and licence fee.

Table 1. Costs per hectare 2013.

Expense item	\$/ha
Fertiliser	546
Fuel and oil	403
Wages - Employees	380
Licence fee - Bollgard	310
Depreciation	227
Contract farming and ripping	215
Contract picking	176
Other	166
Water charges	160
Cartage	132
R & M - Pumps and earthworks	130
R & M - Farming plant	123
Insurance	110
Seed	107
Chemical application	106
Chemicals - Herbicides	84
Cotton picking wrap and sundries	78
Consultants	52
Administration	52
Electricity	45
Chemicals - Defoliant	42
Licence fee - Roundup ready	39
Chemicals - Insecticides	35
Hire of plant	32
Wages - Proprietors	31
Motor vehicle expenses	19
Chemicals - Others	5
Chipping	3
Total average cost per hectare	3,808

Note that this information comes from a sample of growers, totalling 11% of total harvest and favouring large farms (respondent average of 1500 ha of cotton)

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Over time, the Bollgard licence fee has increased over 170% since 2004 on a rolling three-year average, fertiliser costs increased by 68% and seed costs increased 42%. Insecticide costs fell (down 72%) and chipping costs have fallen 95%. Electricity, fuel and oil costs have been variable.

The Boyce Cotton Comparatives data shows that energy costs make up around 11% of production costs – mostly through fuel (10%) with electricity a small cost at around 1%.

A study published in 2015 looked explicitly at Improving energy on irrigated cotton farms in Australia¹⁸⁷. It found broadly similar costs and shares of energy and noted that:

Generally, half of the direct energy consumed will be through irrigation, and about 25% will be used for high load tractor operations during the field prep and post-harvest phases of cotton production,

- *A single pump make and model is used to pump up to 60% of the water volume in the industry, and uses up to 30% of the total direct energy of the industry*
- *Significant tractor energy savings of up to 20% are possible with correction of tractor and implement setup*
- *Diesel fuel provides at least 90% of the direct energy used on farm*
- *Expenditure on diesel fuel is at least 85% of the total direct energy expenditure*
- *The median direct energy expenditure across 198 farm results is \$298 per hectare across the two separate data sets, and represents 8.5% of 2013 average cotton production costs reported in industry as \$3627 per hectare*

¹⁸⁷ National Centre for Engineering in Agriculture (2015) *Energy Efficiency on Irrigated Australian Cotton Farms* University of Southern, Queensland, Toowoomba

Appendix 13. Determinants of cotton price

The price that a grower receives for a load of cotton is essentially determined by the world market. This price is dependent on a number of diverse factors well beyond the control of the grower. These including the state of the world economy, agricultural politics, fashion trends, synthetic fibre price, weather, natural disasters and the prevailing conditions of supply and demand. It is stated that “Australia’s growers produce very high quality cotton with low contamination that is in demand on the world market and commands a premium price”¹⁸⁸.

While there may be a premium for Australian cotton it is generally small compared to the basic price. The major influence on the price for Australian cotton are the relative value of the Australian and American dollar, and world cotton prices as given by various indicators e.g. Intercontinental Commodity Exchange (ICE) No.2 Cotton futures contracts.

There are a range of minimum quality parameters that need to be met it appears that in general exceeding those parameters does not lead to higher prices to the grower. There may be some very small exception to this for the highest quality premium cottons¹⁸⁹.

“The price that a grower receives for each bale of cotton produced is set by the world market. This price is dependent on a number of factors including the state of the world economy, agricultural politics, fashion trends, synthetic fibre price, weather, natural disasters and cotton’s own supply and demand.

Cotton growers ‘sell’ their cotton to one of a number of independent Australian merchants who then sell it into the world’s markets, aiming to get the best price possible. It’s a very competitive and transparent market”¹⁹⁰.

Australian cotton merchants are represented by the Australian Cotton Shippers Association and membership includes: Auscott; Cargill; China National Cotton Corporation (CNCGC); Plexus Cotton Australia; QCotton; Reinhardt; S&G Cotton; Twynam Agricultural Group; Glencore Grain; Namoi Cotton and Omni Cotton.

Cotton marketing enables farmers to price crops two or even three years before they are planted. These forward marketing strategies tend to increase the average price received for cotton farmers for their product. Forward marketing generally attracts a premium of \$10 - \$50 a bale, with a seasonal average of \$25/bale¹⁹¹¹⁹².

¹⁸⁸ <http://cottonaustralia.com.au/cotton-library/fact-sheets/cotton-fact-file-the-economics-of-cotton-in-australia>.

¹⁸⁹ see <http://www.austsupercotton.com.au/>

¹⁹⁰ Cotton Australia Fact Sheet: *The Economics of Cotton in Australia*

¹⁹¹ personal communication D Lindsay, Marketing Manager, Namoi Cotton January 2010 (Dr Kim Houghton)

¹⁹² Powell, J. and Scott, F. (2011), *A Representative Irrigated Farming System in the Lower Namoi Valley of NSW: An Economic Analysis. Economic Research Report No. 46*, Industry & Investment NSW, Narrabri. p27

Appendix 14. Farm scale drivers of change identified in literature to date

Looking at common themes in the reports from CRDC may indicate some of the areas which are seen to be key challenges at the production stage of the cotton industry, e.g. herbicide resistance, water efficiency, various pest and disease issues, particularly emerging diseases, and nutrient applications.

At the 17th Cotton Conference, papers were presented on a variety of topics. There were a lot of papers on biological threats such as chemical resistance, and even new diseases. Several papers discussed issues and solutions related to soil nutrients. A few related to human capacity and post-farm aspects of the industry¹⁹³.

In the *Cotton Production Manual 2014*¹⁹⁴, CRDC and Cotton Australia present the overarching industry's view on factors a producer would need to consider before choosing to go into cotton. These considerations, although designed to educate the potential grower, may give an insight into some of the challenges of the industry expanding to new growers. These issues include: understanding a new type of production system; access to machinery and/or contractors in busy seasons; agronomic knowledge; significant time commitment; compliance with chemical use and GMO responsibilities; availability of water; high costs and risks; effects of spray drift on neighbours; marketing; and access to specialists such as consultants.

The *Cotton Practices Survey 2013* also asked cotton growers for their perspective on influences on profitability and productivity. As the figure over page shows, respondent's views varied widely about how they envisaged different scenarios would affect their profitability. As the survey authors identify, the polarised responses for the perceived impact of 'no in-crop rainfall', likely reflects that for growers of dryland cotton, rainfall is essential, whereas this is mitigated by irrigation for other growers. The perceived impact of these scenarios is influenced by the values chosen by the authors, but it is interesting, nonetheless, to note the perceived high impact of both price and *Heliiothis armigera* being resistant to Bollgard cotton.

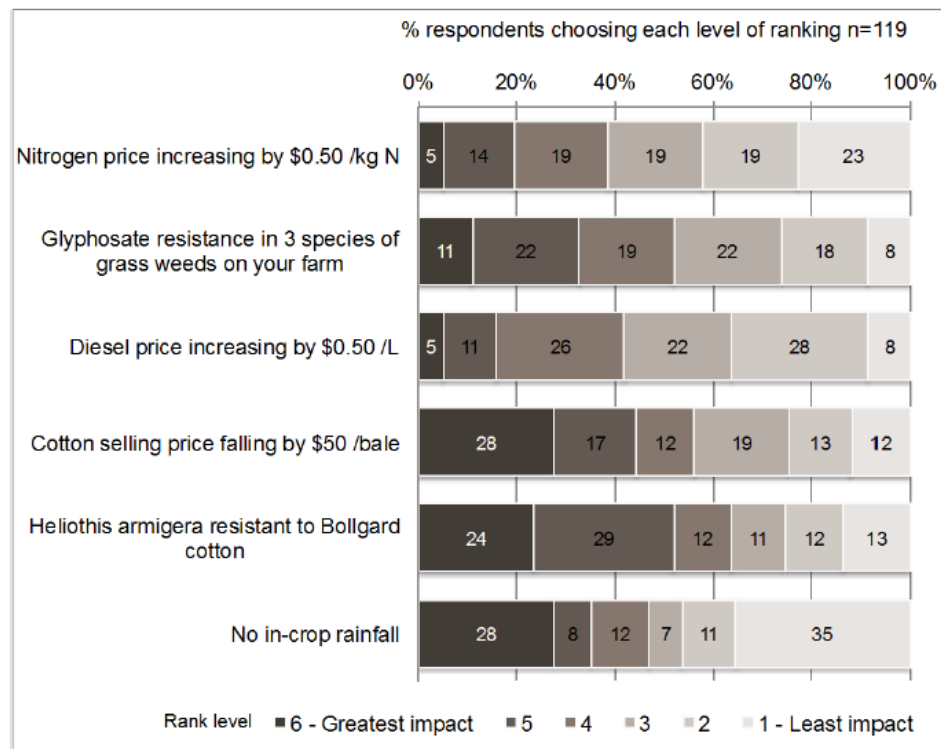
In the same survey, growers were asked about the limitations to the production of their own system. Water and weather were the most frequent answers. For limitations to profitability, yield, price and water were the most frequent answers. Growers identified quite a wide range of key reasons for above average yields, including: weather, timing, water, nutrition and attention to detail. This survey did not ask about perceived resilience, or even productivity or profitability over multiple seasons.

¹⁹³ Cotton Research and Development Corporation (2014) *17th Annual Australian Cotton Conference: Conference papers and e-summaries*. CRDC, Narrabri.

¹⁹⁴ Cotton Info Team (2014) *Australian Cotton Production Manual 2015*. Cotton Info Team.

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Figure 61 Perceived impact on cotton gross margin of hypothetical scenarios



Of these 'hypothetical' scenarios, which would you expect to have greatest impact on your cotton gross margin? Rank in order of impact where 1 = least impact and 6 = Greatest impact

Appendix 15. Farm scale trends identified in literature to date

CRDC commissions annual Australian Cotton Comparative Analysis reports that present seasonal information from growers who chose to contribute farm data and who were able to grow from planting to harvesting with 'near normal irrigation practices' that year. Costs for crops that failed because of hail or flood were excluded from the analysis. The 2013 report compares the top 20% of growers, the bottom 20%, low cost operators and large scale farmers to the average. The top and bottom 20% are calculated based on profit, but assuming an average price for all cotton, as growers use the information to help them to identify good farming, rather than good marketing, practices. It also provides comparisons between the different valleys. All this data has a high level of detail on the average income, expenses, yield, value of crop, water use, labour, rotations and equipment for each of the farmer categories above. It includes averages for the past ten years and the past three bottom years in addition to 2013 data. Overall, the data from the past ten years suggests the following trends:

- *The value per bale is increasing ever so slightly, although we have seen no real growth (after inflation).*
- *There has been significant growth in cost per hectare.*
- *The yield per hectare is increasing, although this increase is occurring at a reduced rate.*
- *The operating profit per hectare for the average grower is increasing slightly.*
- *The operating profit per hectare for the top 20% of growers is increasing at a slightly faster rate compared to the average.'*

The authors do, however, identify that the report should not be used to assess the health of the industry as it is only a specific sample. The exclusion of failed crops means that the data cannot reliably be used to assess the industry overall. It is also likely to present a rosy view of the industry, as enthusiastic or dedicated growers may be the most likely to make the effort to participate. Although not usually integrated into the analysis, the *Cotton Growing Practices Survey* (2013)¹⁹⁵ and the *Third Environmental Assessment*¹⁹⁶ both note that the average cotton producer is also producing other crops and often grazing sheep or cattle as well.

In the *Third Environmental Assessment*, environmental performance trends for the industry are identified. They are included here, as they mostly appear to be initiatives implemented at the farm level. Improvements from an environmental perspective include improvements in environmental stewardship, annual water efficiency increases of 3 to 4% through an uptake of R&D, significantly reduced pesticide use through use of genetically modified varieties and integrated pest management, energy efficiency improvements, uptake of certification and information through CRDC's Best Management Practice and improved soil, riparian and native vegetation management. The report notes that certification of best practice could improve and that improved ecosystem management is having positive outcomes for biodiversity and ecosystem services, but needs better monitoring, partly as a result of the difficulty in establishing useful indicators.

¹⁹⁵ Roth, G. (2013)

¹⁹⁶ Inovact Consulting (2012)

Appendix 16. Statistics highlighting variability of cotton production

Cotton Australia Annual Booklet statistics highlight variability

	2000-01	2009-10	2011-12	2012-13	2013-14	2014-15
Number of farms				1,250	1,181	796
Area ha			566,000	444,840	421,610	196,698
Ave area ha				467	496	495
Bales (m)			5.3	4.15	4.1	1.9
Yield irrigated bales/ha				9.7	10.4	
Yield dryland bales/ha				4.8	5.1	4.2
% dryland				20	5	7
Base grade %				85	95	65
Premium/high %				44	75	21
Price \$/bale				451	431	474
Water use ML/ha				5.2	5.2	7.8
Bales/ML	1.1	1.9				

- Big drop in dryland production 2012-13 to 2013-14 – BUT little drop in total area or bales
- But another big drop in total production to 2014-15 but NOT due to drop in dryland growing – signs of higher water use across the whole crop
- Price not related to % of crop which is ‘premium; or ‘high quality’
- Number of cotton farms down 32% 2013-14 to 2014-15, hectares down 53%
- 20% dryland and 80% irrigated in 2013 (bigger harvest); 5% dryland in 2014, 7% dryland in 2015
- Price series: \$354 to \$444/bale
- Quality mix shows no relationship to price (so growers can’t pursue the ‘quality’ point of differentiation to support increasing growing costs ...):
- 2012-13 85% base grade only 15% discounted, amongst base grade 24% premium, 20% high, 41% medium, 11% low and 4% lower (price \$451),
- 2014 95% and 75% high or premium – but not reflected in price (\$431),
- 2015 65% and 21% premium or high– quality fall not reflected in price of \$474
- 99.2% of growers use ‘biotech traits cotton’
- Pesticide use reduced by 87% over 10 years (95% over 15 years and 0.2g of insecticides for every kg of cotton lint produced)
- Less than 5% of a catchment used to grow cotton
- 40% of cotton farms are native veg (42% in 2014-15)
- 40% increase in water use efficiency – now 1.9 bales/ML (was 1.1 in 2000-01)

2013 and 2012 crop reviews from Boyce highlight the variability in growing conditions that growers need to adapt to.

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THE 2013 CROP – ANALYTICAL REVIEW

It would appear that there is no such thing as a normal year!

The 2013 crop proved to be a difficult one with very little in-crop rain up to the end of January, heatwave conditions throughout that month, severe flooding in many areas and finally an extended dry picking window.

In summary, the 2013 growing season will be remembered for the following:

- growers, in hindsight, tended to plant more cotton than they had water for
- very little in-crop rain until the end of January
- severe heat wave conditions throughout January with some areas experiencing twice the average number of days over 35 degrees Celsius
- fields being ploughed out due to lack of water
- flooding rains at the end of January over most of eastern Australia, with the western Macintyre valley experiencing the worst floods on record
- very little rain over an extended picking period.

Early planting, small seed and early cold shock days continue to provide plant establishment issues, although it is notable that the daily average temperature this season was well up in the southern regions.

As a result of elusive spring rains, minimal dryland cotton was planted. As the season stayed dry, the decision not to plant was, in most cases, vindicated. The reduced dryland planting meant decreased pressure on industry service providers. There was some pressure on picking contractors' rates although ginning rates continue on an upward trend.

THE 2012 CROP – ANALYTICAL REVIEW

The year 2012 was another record breaker – the industry continues to re-build and realign itself after the long drought.

The increased area planted to dryland cotton and the incredible dryland yields meant increased pressure on cartage and ginning infrastructure at the end of the season.

While positive for most dryland crops, in general it was an abnormally wet season, with disastrous flooding having a major impact on yield and some impact on costs.

A cool start and the physically smaller seed meant replanting was common and this continues to impact the total average cost of planting seed. Seed size is also driving the reduction of seed income per hectare.

With three years of solid data since the long drought, this analysis is giving us a good insight into the 'new industry'. It is important to understand that where a crop has not been picked due to flooding or some other disaster other than hail, the expenses relating to the affected area have been excluded from the sample. This is worth noting given the extent of flooding this season.

For the average grower, the total income per hectare (\$4,793) is well down from the previous year, with yield and price both playing their part. The difference in yield between the top 20% and the average (of around 1.7 bales/ha) is telling – some growers can spend

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the same on the crop but consistently come out with an extra \$700 of income on average per hectare - the result is significant. The slightly reduced yield of the average continues to have a negative impact on the yield curve, although the reports of some very high yields and some massive results within fields would suggest this trend may well be about to turn around.

Climate variability continues to be a major factor impacting whether a grower is in or out of the top 20%. In 2012, the major event was flooding. In our view, it may be useful to reflect on whether the outcome of the event (not the event itself) could have been changed in a cost effective manner, and what impact that would have had on profitability. If we can't stop these high-impact events, how do we minimise their impact on profit? In the example of flooding, what is the cost / benefit of revising the height of your levies or improving your ability to get the water off the field at a faster rate?

Expenses per hectare were up from the previous year. While it was a very light insect year, and contract picking costs (overall) fell, the increase in fertiliser costs, contract farming and other farm overheads is alarming. The increase in cotton wrap is a solid confirmation of the up-take of new picking technology by the industry. While the benefits of round bale technology are obvious, the cost outcome may well be different for individual growers depending on their opportunity costs. In our view this requires individual analysis by each grower.

The top 20% continue to have lower costs per hectare than the average, with a difference of \$77/ha in 2012. We note this difference is lower than in previous years.

In our view the industry continues to be an early adopter of technology. At the industry level, this is a tremendous positive as it shows the innovation that has driven the industry. However from a profit perspective, individual growers need to know where their profit comes from, as the early adoption of technology at the micro-level is not always conducive with maximising profit. We believe each technology adoption needs to be framed initially around ongoing cost minimisation or yield maximisation, and secondly from the point of view of the initial capital cost and other benefits. This equation needs to be kept in perspective but the answer could be different for each grower.

The cost of chipping continues to reduce such that it is now a negligible expense. This is a sober reminder of just how quickly things can change in this industry. We recommend that growers spend some time thinking about where the industry is headed in an attempt to be ahead of the game in the two main areas that impact profit – maximising yields and ensuring costs are at a minimum.

Profits for both the average and top 20% continue to be close to historically high levels, although nowhere near the 2011 results.

Taking advantage of a solid lint price continues to be a massive issue for the industry and there seems to have been a shift in marketing and financing options available for growers. As discussed in previous analyses and at the many grower meetings we attend, the ability to lock in a price for lint when water is available has been an important factor in underpinning the profit of the industry to date. In our view, since the GFC and the recent price spike, merchants have been struggling to provide products to growers that continue to give growers this ability.

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This year we have again included trend lines in some of the graphs presented. Some interesting trends from 1997 to 2012 have emerged, including:

- The value per bale is increasing ever so slightly, although we have seen no real growth (after inflation).
- There has been significant growth in cost per hectare.
- These two statistics confirm the decreasing terms of trade for the industry.
- The yield per hectare is increasing, although in our view, this increase is occurring at a reduced rate.
- The operating profit per hectare for the average grower is relatively static.
- The operating profit per hectare for the top 20% of growers is increasing.

The drought distorted the data in the 2003, 2004 and the 2007 to 2010 years. Accordingly, when using this analysis to assist with a review of your own operations and with the preparation of budgets, we recommend that you look at the 2011 and 2012 and years' data as these were the last full production years.

Appendix 17. Survey 1: general resilience (industry)

Benchmarking survey

August 2014

A first activity for the project was to administer a survey at the Australian Cotton Conference, held 5 to 7 August 2014 at the Gold Coast. The aim of the survey was to gain an insight into perspectives on key issues for the industry into the future. Participants in the survey ranged across the value chain of the cotton industry, from farm staff and growers through to processing and marketing. Conference participants who were visiting the trade display were randomly selected by project researchers, Anne Currey and Jeremy Cape, to take part in the survey. Anne and Jeremy introduced themselves, explained the aim of the survey and invited responses. Only two people refused this invitation to participate. The survey was administered on 6 and 7 August, and responses recorded for 42 people representing key sectors in the industry, i.e. farm staff and growers, agency and private advisors, researchers, equipment and input suppliers and processors.

Summary

Respondents to the survey were from across the value chain in the industry and from all cotton growing regions other than Menindee.

Water was clearly the most important on-farm issue for the future, followed by climate variability. Availability of skilled labour, cost of inputs and commodity price.

Ongoing research and development was by far the most highly rated industry issue for the future, with 60% of respondents identifying it.

Ability and willingness to innovate, access to markets and competition, skilled people from farm to marketing and financial robustness all scored similarly as being important.

A feature of respondents was their positive attitude to the industry and a sense of optimism.

Most saw it as being able to respond well or very well to major threats. Key strengths focussed on four areas:

- communication and information sharing
- an innovative and adaptive culture
- industry organisation and cohesion
- management and business ability.

About the respondents

There was a good geographical spread of respondents, with Menindee being the only cotton growing region not represented. Fifteen respondents worked in all regions, 14 in Goondiwindi/Moree and 8 in the Darling Downs. There were between 1 and 7 respondents for the other regions.

The biggest proportion of respondents (40%) had been in the industry for more than 20 years while the smallest proportion (15%) had worked in it for five years or less.

Responses from 15 cotton growers (including four farm managers/workers and two corporate growers) were recorded. Most Australian farms run more than one enterprise, and the survey shows that cotton farming is no exception. Of the farmers and farm workers questioned no properties were totally given to cotton production, rather it represented between 25 and 90% of production.

Not surprisingly, key determinants of how much of the farm was devoted to cotton production in any one year were seasonal conditions and availability of water. Production on eight farms had stayed the same over the last five years and on seven had fluctuated based on season.

In this context, three quarters of growers used irrigation either for all or most of their crops in the last 5 years; only two growers were totally dryland.

The percentage of the total business associated with cotton was lowest for input and equipment suppliers, and for most this was between 10 and 70%. In the last five years, however, the percentage of business with the cotton industry had increased, in a number of cases because conditions in other agricultural industries were poorer in comparison.

Issues for the future

Respondents were shown a list of issues and were asked to identify which of these were the three most important for the future, both on farm and for the industry as a whole. Respondents could also nominate issues that weren't included in the list.

On-farm issues. By far the most important on-farm issue identified for the future was **water**, with 32 respondents identifying it as one of their three choices. The second most identified issue, which was related to this, was **climate variability** (24 respondents). The next three issues with similar scores were cost of inputs (19 respondents), availability of skilled labour (15) and commodity price (15).

Access to information, management skills, soil degradation and pests and diseases scored lowest.

Energy was the only other issue to be nominated - by two people.

Industry issues. As with on-farm issues, there was an industry issue that stood out as being seen as most important by a significant proportion of respondents – **ongoing research and development** (26 respondents or 62%). Four issues were rated by between 15 and 19 respondents – ability and willingness to innovate (19 respondents), access to markets and

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competition (17) and skilled people from farm to marketing and financial robustness (15 each).

Leadership (5), government policy and regulations (6) and infrastructure (6) scored lowest.

Influencing decision making

Half of the respondents (20 people) felt unable or not very able to influence decision making in the industry while a quarter felt they were able to some degree to influence decision making (a score of 3). There was no particular pattern to responses so answers from growers, input suppliers, researchers, advisors and processors varied from 1 through to 5.

Recent major threats

A variety of recent major threats were identified. Those nominated most were:

- Water, e.g. access, regulations, allocations, MDB Plan (score of 12)
- Pest and diseases, e.g. managing resistance, overuse of pesticides, containing outbreaks such as mealy bugs (score of 14)
- Drought and floods, e.g. response and providing information (score of 10).

Other issues included supply and managing stockpiles.

In general, respondents were positive about how the industry had reacted with 27 saying it responded well or very well. Only three people said it reacted very badly or not at all well to the threats of competition from synthetic fibres, water access and the MDB Plan.

Key strengths of the industry

Four themes emerged about the key strengths (see table over page):

- Communication and information sharing
- Innovative and adaptive culture
- Industry organisation and cohesion
- Management and business ability.

It was noticeable that respondents to the survey had a sense of pride and confidence in the industry, which they regard as innovative, unified and able to share information and knowledge.

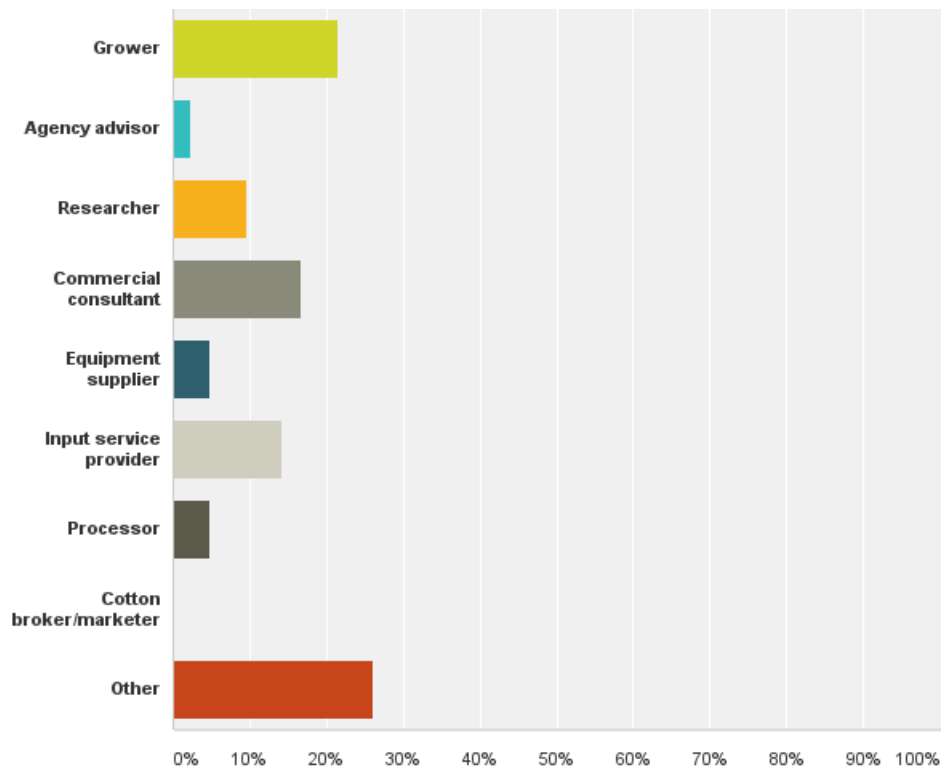
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Table. Key strengths of the cotton industry..

Communication and information sharing	Innovative, adaptive culture	Organisation and industry cohesion	Management and business ability
Small size, unity and willingness to share information	It is innovative Innovation and collaboration	Well organised to focus on addressing problems	Profitability; R&D to support the industry which has kept it ahead of other industries
Ability to go on the front foot; rigorous collaboration within the industry; willingness to share; future oriented	backed by R&D Resilience, adaptability and responsiveness	The core of growers and organisation that surrounds it; energetic and well-coordinated cohesive industry	Level of investment Ability to respond to market forces and change crops as a result
Communication and extension within the industry	Like-minded people	Fairly united	Resilient; knowledge and commitment to growing the crop; attracts professionals
Ability to get information	Industry attracts people willing to have a crack	Sense of community	because it is a high input, high value crop;
Very good information resources; ability to share information readily and openly	Adaptable to change; ability to adopt innovations	People and sense of community	sophisticated and good managers and adopters of technology
Unity and information sharing	Innovative and technically savvy	Diversity - geographic and people	Professional ability to market itself
Information exchange	Ability to innovate and adopt new technology	It is the most focused industry and works as a whole	Perfectly free to go broke - no subsidies
Diversity of people; knowledge sharing	Ability to innovate and develop use able technology	Wealth of talent through the chain	
Willingness of people to share information	Adoption of new technology		
Openness and willingness to share information	Innovation culture	Age of cotton growers - broad demographics	
Communication along the supply chain	Focused on R&D; technology uptake; forward thinking	Social capital	
Infrastructure/help/knowledge sharing/resources	Ability to innovate and adapt Initiative, innovation	Its people and their willingness to succeed	

Survey responses

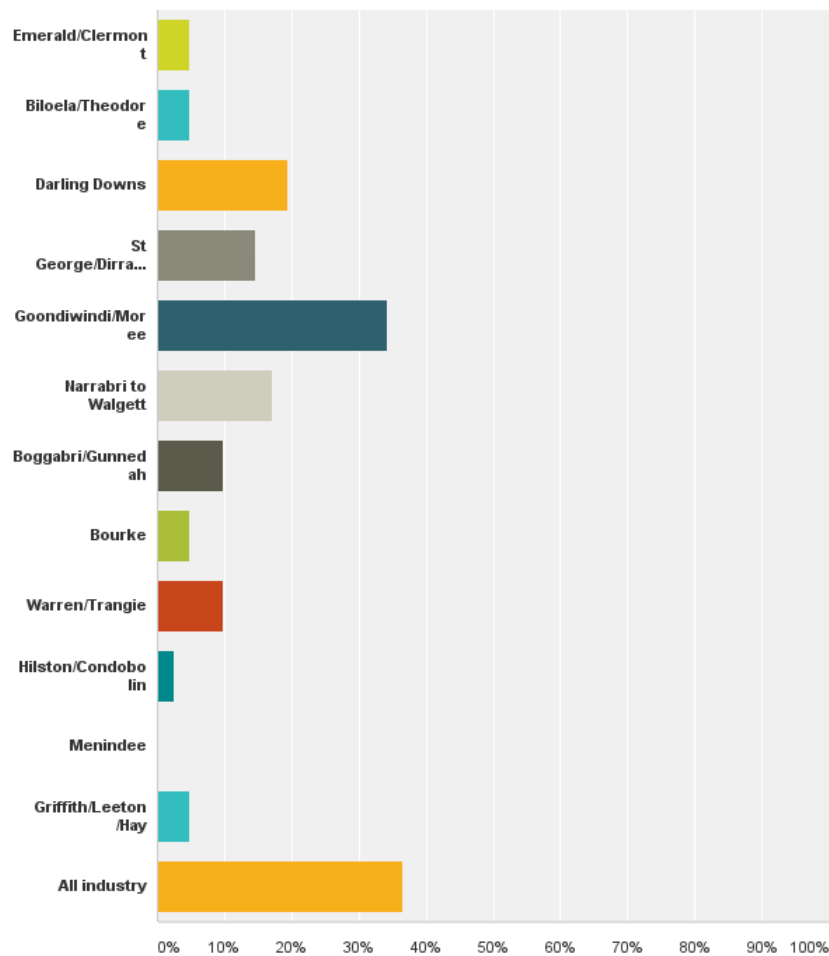
1. What is your main role in the industry?



Answer Choices	Responses
Grower	21.43% 9
Agency advisor	2.38% 1
Researcher	9.52% 4
Commercial consultant	16.67% 7
Equipment supplier	4.76% 2
Input service provider	14.29% 6
Processor	4.76% 2
Cotton broker/marketer	0.00% 0
Other	26.19% 11
Total	42

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2. What region do you mostly work in?

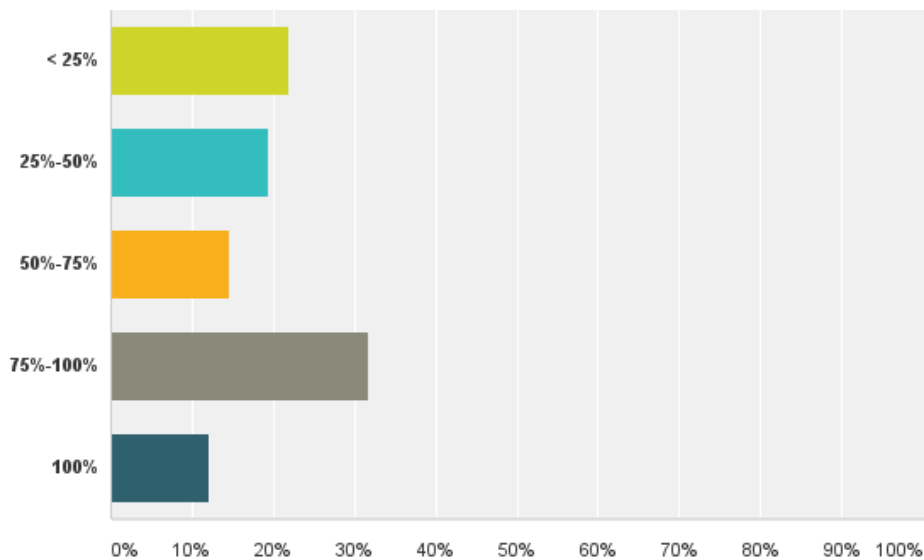


3. How long have you worked in the industry?

Answer Choices	Responses
0-5 years	14.29% 6
6-10 years	19.05% 8
11-20 years	26.19% 11
More than 20 years	40.48% 17
Total	42

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4. What percentage of your business has been associated with cotton, on average, over the last five years?



5. How much has this changed over the past five years?

Stayed the same/no change – 20 responses

Fluctuated based on season and water allocation – 7 responses

Gone from 15 staff to 100 staff (labour hire company)

Decreased from 100%

Gone from 0 to 80% as the result of a research project

Has gone from nothing to 80%

Grown by 5 to 10%

Got less

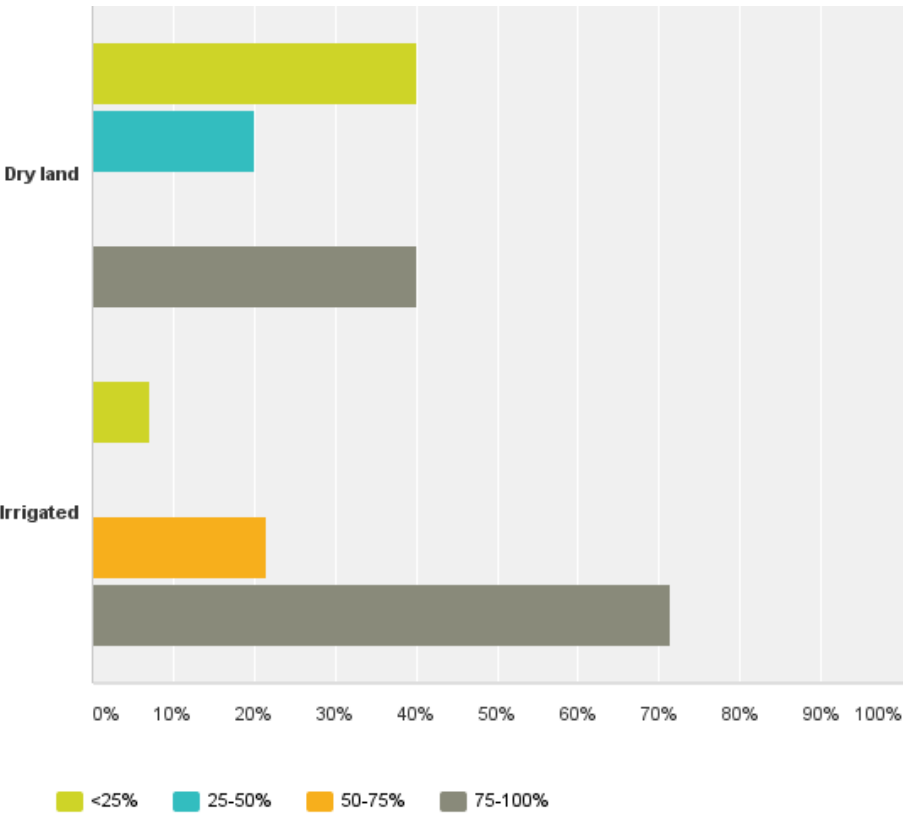
Increasing

Gone from 0 to 40%

It has increased because of a decline in business in other agricultural industries

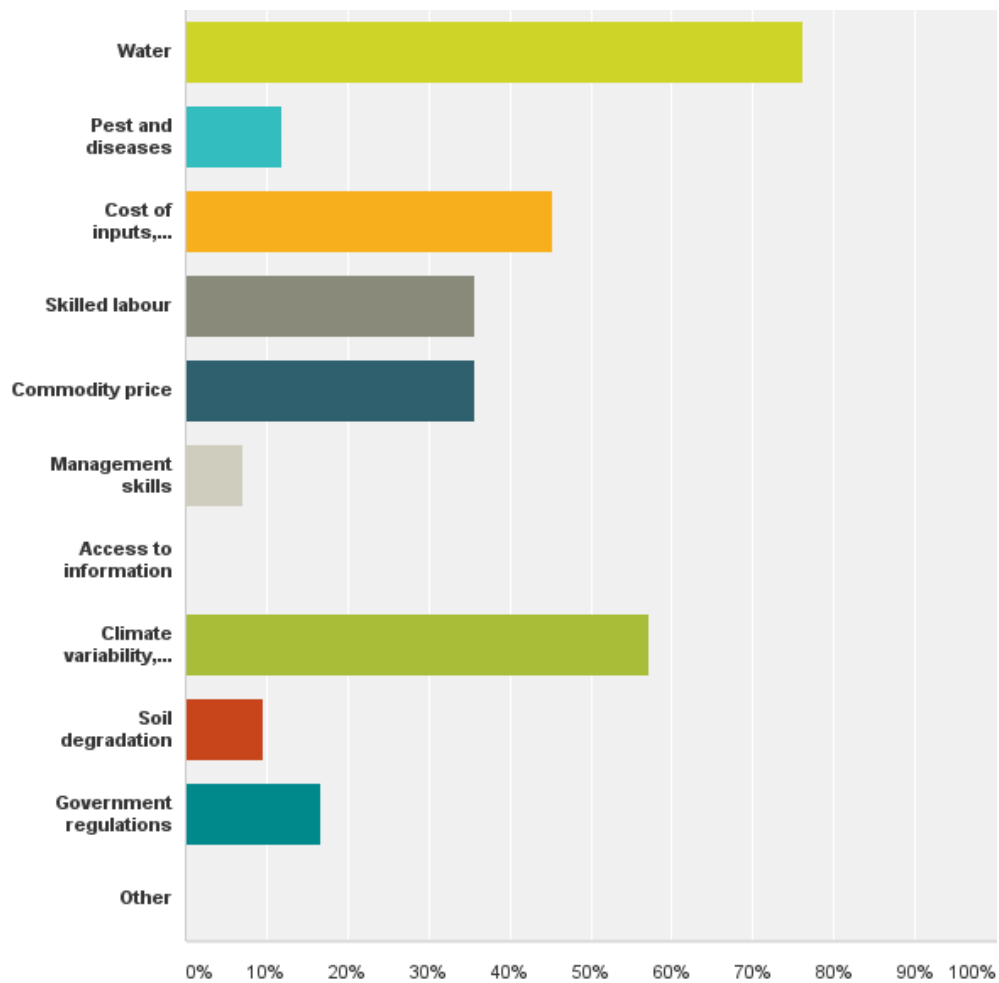
Decreased. Now 5%

6. If you are a grower, what percentage of your crop is dryland and what percentage was irrigated over the last five years?



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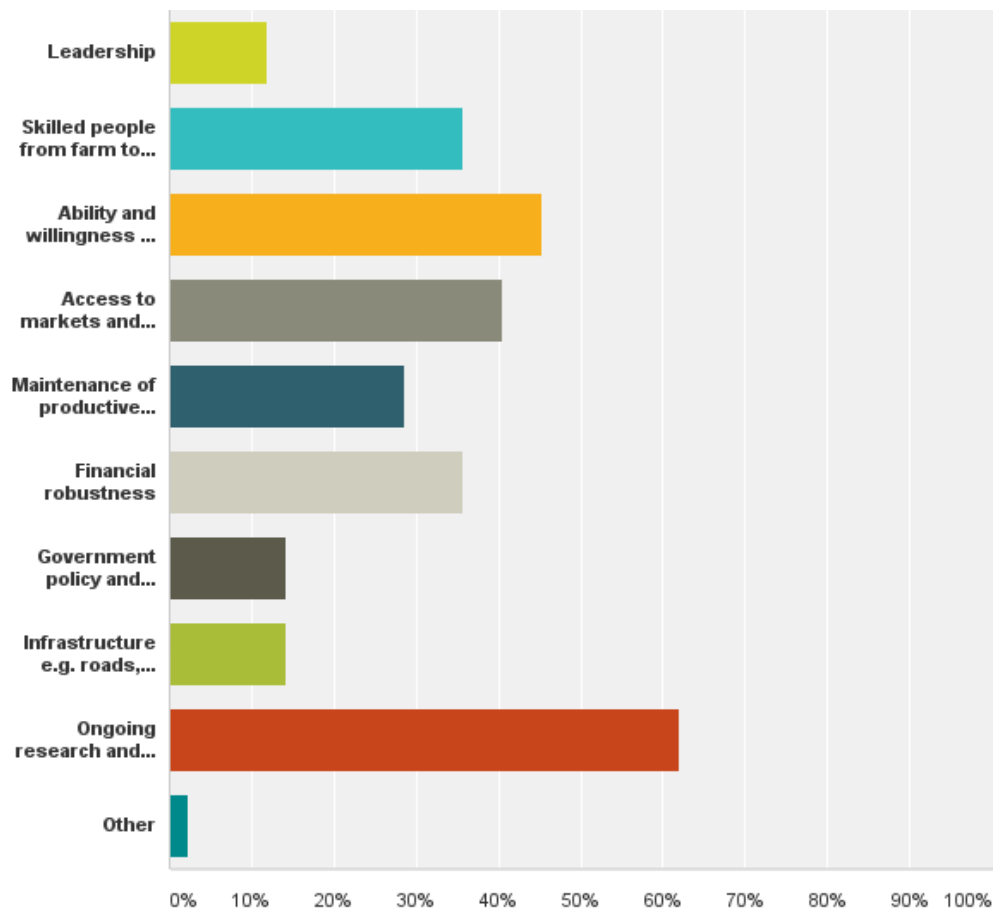
7. Thinking about cotton production on a farm scale what do you think are the three most important issues for the future?



Answer Choices	Responses	
Water	76.19%	32
Pest and diseases	11.90%	5
Cost of inputs, fertilizer, fuel etc	45.24%	19
Skilled labour	35.71%	15
Commodity price	35.71%	15
Management skills	7.14%	3
Access to information	0.00%	0
Climate variability, drought, floods	57.14%	24
Soil degradation	9.52%	4
Government regulations	16.67%	7
Other	0.00%	0
Total Respondents: 42		

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

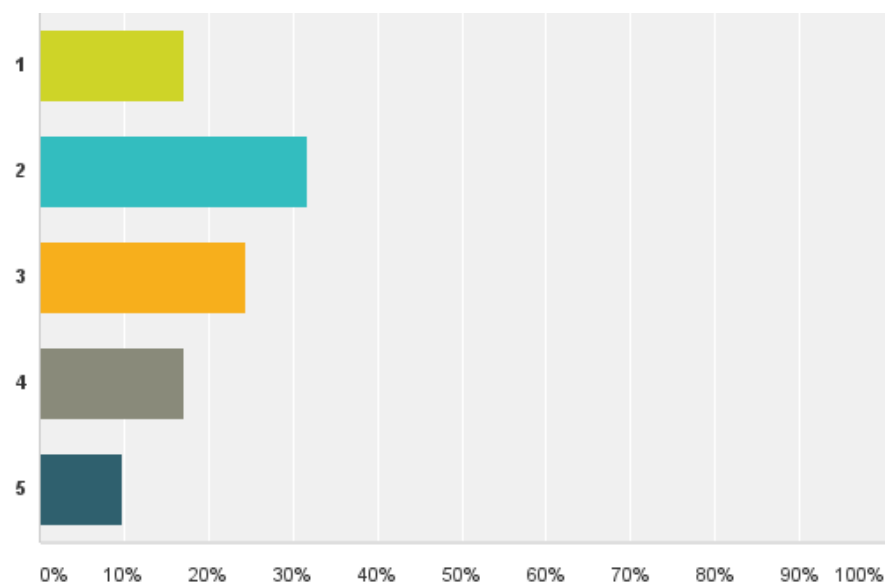
8. Thinking about the industry as a whole what do you think the three most important issues are for the future?



Answer Choices	Responses	
Leadership	11.90%	5
Skilled people from farm to marketing	35.71%	15
Ability and willingness to innovate and adopt new technology	45.24%	19
Access to markets and competition	40.48%	17
Maintenance of productive natural resources	28.57%	12
Financial robustness	35.71%	15
Government policy and regulations	14.29%	6
Infrastructure e.g. roads, railways, communications	14.29%	6
Ongoing research and development	61.90%	26
Other	2.38%	1
Total Respondents: 42		

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

9. On a scale of 1 to 5 with 1 being not at all able and 5 being very able how able are you to influence decision making in the industry?



Answer Choices	Responses
1	17.07% 7
2	31.71% 13
3	24.39% 10
4	17.07% 7
5	9.76% 4
Total	41

10. Thinking about a recent major threat to the cotton industry; what was that threat and how well do you think the industry responded?

The seven most important words used to describe threats by respondents were as follows. Size of text indicates number of references so that drought and water were the threats identified most often.

Drought MDB Plan Mealy Bug Outbreak R&D
Resistance **Water**

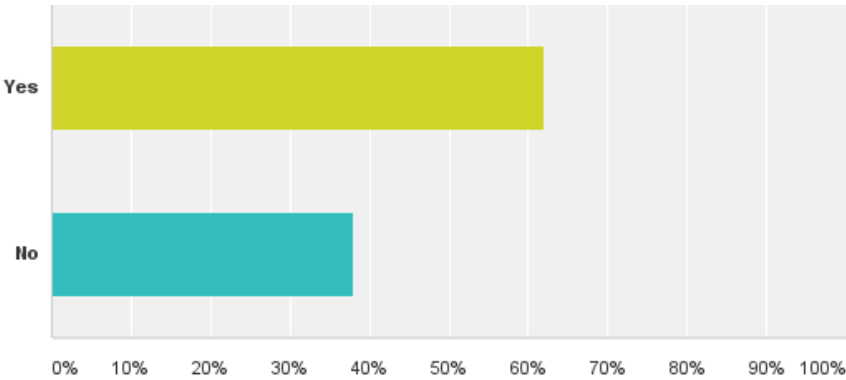
Resilience Assessment of the Australian Cotton Industry at Multiple Scales

Answer Choices	Responses	
Very badly	2.38%	1
Not at all well	4.76%	2
Okay	28.57%	12
Well	23.81%	10
Very well	40.48%	17
Total		42

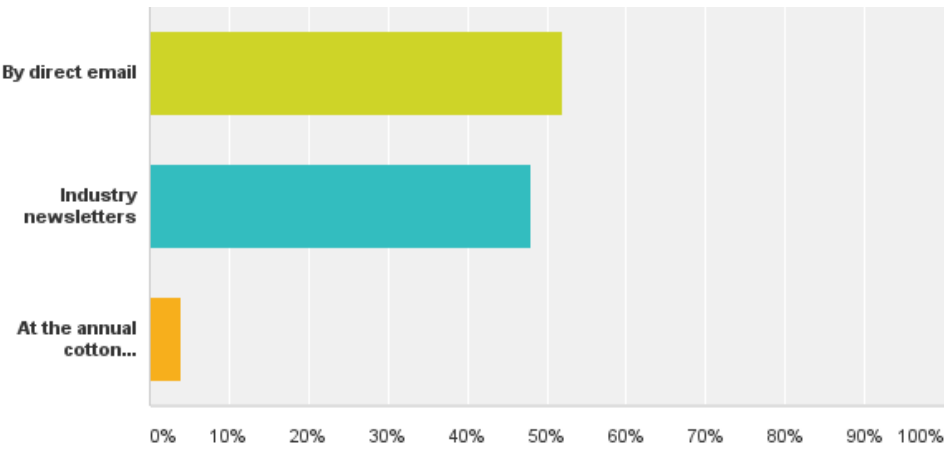
11. What do you think is a key strength of the cotton industry

Communication and information sharing	Innovative, adaptive culture	Organisation and industry cohesion	Management and business ability
Small size, unity and willingness to share information	It is innovative	Well organised to focus on addressing problems	Profitability; R&D to support the industry which has kept it ahead of other industries
Ability to go on the front foot; rigorous collaboration within the industry; willingness to share; future oriented	Innovation and collaboration backed by R&D	The core of growers and organisation that surrounds it; energetic and well-coordinated cohesive industry	Level of investment Ability to respond to market forces and change crops as a result
Communication and extension within the industry	Resilience, adaptability and responsiveness	Fairly united	Resilient; knowledge and commitment to growing the crop; attracts professionals because it is a high input, high value crop; sophisticated and good managers and adopters of technology
Ability to get information	Like-minded people	Sense of community	Professional ability to market itself
Very good information resources; ability to share information readily and openly	Industry attracts people willing to have a crack	People and sense of community	Perfectly free to go broke - no subsidies
Unity and information sharing	Adaptable to change; ability to adopt innovations	Diversity - geographic and people	
Information exchange	Innovative and technically savvy	It is the most focused industry and works as a whole	
Diversity of people; knowledge sharing	Ability to innovate and adopt new technology	Wealth of talent through the chain	
Willingness of people to share information	Ability to innovate and develop use able technology	Age of cotton growers - broad demographics	
Openness and willingness to share information	Adoption of new technology	Social capital	
Communication along the supply chain	Innovation culture	Its people and their willingness to succeed	
Infrastructure/help/knowledge sharing/resources	Focused on R&D; technology uptake; forward thinking		
	Ability to innovate and adapt		
	Initiative, innovation		

11. Would you like to be kept up to date with this research project?



12. If you answered yes, how would you like to be kept up to date?



Appendix 18. Survey 2: general resilience (farm and region)

GENERAL RESILIENCE SURVEY

Cotton Industry Workshops

Narrabri, Emerald & Griffith

June 2015

Background

This survey asks you about some of the attributes of general resilience.

We are interested in your responses for two scales – farm and region.

While some of these attributes can be quantified, many can only be looked at in a qualitative way. Thinking about them in this way can provide powerful insights into the overall resilience of a system.

This is a self-assessment questionnaire so there are no right or wrong answers. It is not about accuracy, rather this is about capturing your sense of how things are for each of these attributes.

For each statement, responses are required for your estimate of the level (sliding scale from 1 to 5 where 1 = very low and 5 = very high).

Questions 1- 4 apply to the farm scale and questions 5-8 to the regional scale.

Farm scale

These attributes should be considered from a farm scale. Many farms have more than one enterprise so please answer these questions from the farm perspective and not just from the perspective of the cotton enterprise.

Please indicate for each statement a level (score 1 very low to 5 very high)

1. Capacity to self organise - leadership, power and trust

Presence of social networks for people managing and running the cotton farm	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Presence of organizational skills and capacity to address issues as they arise	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Processes in place to develop and support leadership	1 <i>very low</i>	2	3	4	5 <i>very high</i>

2. Capacity to innovate - openness and knowledge

On farm experimentation	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Immigration (people, skills, ideas and capital coming onto the farm)	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Support for innovation (safe areas for experimentation on farm)	1 <i>very low</i>	2	3	4	5 <i>very high</i>

3. Diversity

Social/cultural diversity on farm	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Diversity of income sources	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Ecological diversity on farm	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Biophysical and land from diversity (eg. soil types and land types)	1 <i>very low</i>	2	3	4	5 <i>very high</i>

4. Degree of overlaps (positive redundancy)

Degree of overlaps in important roles and responsibilities on farm	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Degree of reliance on only one enterprise	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Degree to which the farm is connected so that an undesirable shock could be transmitted rapidly	1 <i>very low</i>	2	3	4	5 <i>very high</i>

Regional scale

These attributes should be considered from a regional scale

Please indicate for each statement a level (score 1 very low to 5 very high)

5. Capacity to self organise - leadership, power and trust

Presence of social networks for people involved in cotton production	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Presence of organisational skills and capacity to address issues as they arise	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Ability to influence decisions at a regional scale	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Variety of leadership styles in the region	1 <i>very low</i>	2	3	4	5 <i>very high</i>

6. Capacity to innovate – openness and knowledge

Ongoing support for research and development	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Immigration (people, skills, ideas and capital coming into the region)	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Support for innovation (safe areas for experimentation)	1 <i>very low</i>	2	3	4	5 <i>very high</i>

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

7. Diversity

Diversity (age, gender, roles, culture etc) of social networks	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Range of service providers eg. contractors and other input providers	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Ecological diversity	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Biophysical and landform diversity (eg. soil types and land types)	1 <i>very low</i>	2	3	4	5 <i>very high</i>

8. Degree of overlaps (positive redundancy)

Degree of overlaps in important roles and responsibilities in the region	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Degree of shared understanding between individuals and organisations about major challenges	1 <i>very low</i>	2	3	4	5 <i>very high</i>
Degree to which cotton farms are connected allowing for transmission of undesirable shocks through the region	1 <i>very low</i>	2	3	4	5 <i>very high</i>

Appendix 19. Importance of cotton growing in case study areas

Balonne Shire and St George

Importance of cotton growing

St George is the principle township of the Balonne Shire. The Shire of Balonne is located in Queensland on the New South Wales border some 500 km from the east coast of Australia and has an area of approximately 31,000 km². St George was founded in around 1850 as the district centre of what was then mainly a wheat-sheep area. This was true until the mid-twentieth century, when the community began a transition towards irrigation production, mainly of cotton. The Balonne regional economy has always been highly reliant on agriculture, with 2006 Census data indicating that 36.1% of employment was in agriculture, or 10.6 times the ratio for the whole of Queensland. The value of agricultural production for Balonne Shire in 2005–06 was \$221 million, of which \$134.1 million was crops of mainly cotton (Murray-Darling Basin Authority 2010).

Agricultural production

In 2006, there were 2,485,443 ha of land under agricultural cultivation in Balonne Shire, and approximately 50 cotton growers in the area around St George and Dirranbandi. The majority of this land was used for grazing, with a small proportion used for broadacre crops and with cotton a smaller but economically significant use; the value of agricultural production for Balonne Shire in 2005–06 was \$221 million, of which \$134.1 million was crops of mainly cotton (Murray-Darling Basin Authority 2010).

The MDBA's regional profile for the Lower Balonne (Marsden Jacob Associates et al. 2010a) noted that the St George Irrigation Area covers approximately 19,000 ha, with most of that (12,000 ha) set up for irrigation. Cotton is the dominant broadacre irrigation crop (although some irrigated sorghum, wheat and barley is produced), while smaller areas are under irrigated horticulture (grapes, melons and some vegetables, particularly pumpkins, sunflowers and onions). In 2005–06, approximately 8,700 ha were under cotton, 800 ha under grapes and 200 ha under vegetables. The area planted under cotton has varied considerably in recent years, from under 1,000ha to over 50,000ha, and averaged around 35,000 ha before 2001.

With a reasonable harvest cotton is the largest contributor to agricultural production by value, followed by beef cattle and cereals (see Figure 1).

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

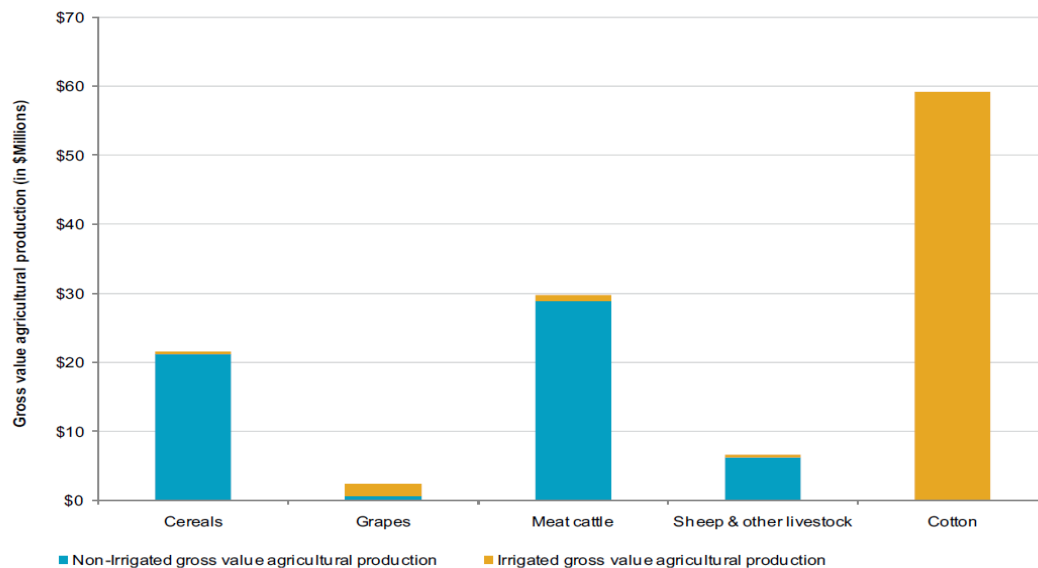


Figure 1. Gross value of agricultural production 2006¹⁹⁷.

Implications

Irrigated farming has allowed the St George community to thrive and grow. The significant decline in population from 2001 to 2006 was quite different to the upward trend in population generally experienced by Balonne Shire over the past 30 years. The population increase occurred at a time when irrigated agriculture became a more significant component of the local economy, offsetting climatic variability and the resultant job losses and population decline that have been experienced in other remote communities where dryland agriculture is the dominant land use. However, a regional economy focused in this way is also clearly vulnerable to changes in external circumstances, and the heavy reliance of the shire's economy on irrigated cotton means that variability of production, for example in recent drought years, have significant flow-on impacts in terms of population, employment and income.

In terms of agricultural employment in St George, about 26% of the town's population is employed in agricultural industries, compared to 41% in Balonne shire as a whole. Of the 400 people employed in agricultural industries in St George, about half are farm managers, and there is relatively little flow-on to labouring (one labourer for every two managers) and 'service to agriculture' which includes activities such as fertiliser spreading, harvesting, agistment and veterinary services. Businesses are predominantly small, but show signs of diversifying in response to drought

St George and its surrounding region are now highly dependent on irrigated agriculture both directly and indirectly as a major source of economic activity and employment; crops account for approximately 60% of the total value of agricultural production. Analysis by Price Waterhouse Coopers in 2000 for the Condamine–Balonne concluded that direct and indirect employment was around 25.5 jobs per thousand hectares, compared to 3 jobs per thousand hectares in dryland farming. In other words, employment intensity in irrigated agriculture is significantly higher than dryland farming.

¹⁹⁷ Murray-Darling Basin Authority 2010, 'Lower Balonne Community Profile', in *Appendix C of The Guide to the Proposed Basin Plan*, Murray-Darling Basin Authority, Canberra. P. 885

The Namoi Valley and Gunnedah

Introduction and history

The Shire of Gunnedah in the North West of NSW covers an area of 5,092 km² and has a population of around 12,000 people. It is part of the Namoi Catchment, located in the upper Namoi valley and with an area of approximately 42,000 km². Gunnedah was one of the first towns in the Namoi Valley. It was established in the 1850s, and had about 500 residents by 1873. The Liverpool Plains, of which Gunnedah was a part, were an extensive pastoral and cropping district at this time, described as “the best watered district of NSW.” As early as the late 1840’s squatters, occupying runs and stations had taken up much of the district. The advent of rail to the town in 1879 led to the development of saleyards, which by the early 1900’s were busy selling cattle, sheep and horses. By this time Gunnedah also had many shops and services including a post office, a courthouse, a police station, a public school, a coach maker, several hotels and a brewery.

Agricultural production

The dominant land use in the Namoi Valley is cattle and sheep grazing. Wheat, cotton and other broadacre crops are grown on the alluvial floodplains. Around 112,000ha were irrigated in 2000 with around 80,000 ha (or over 70%) used for cotton production. Figure 2 shows the gross value of agricultural production for commodities other than cotton in the Namoi Valley.

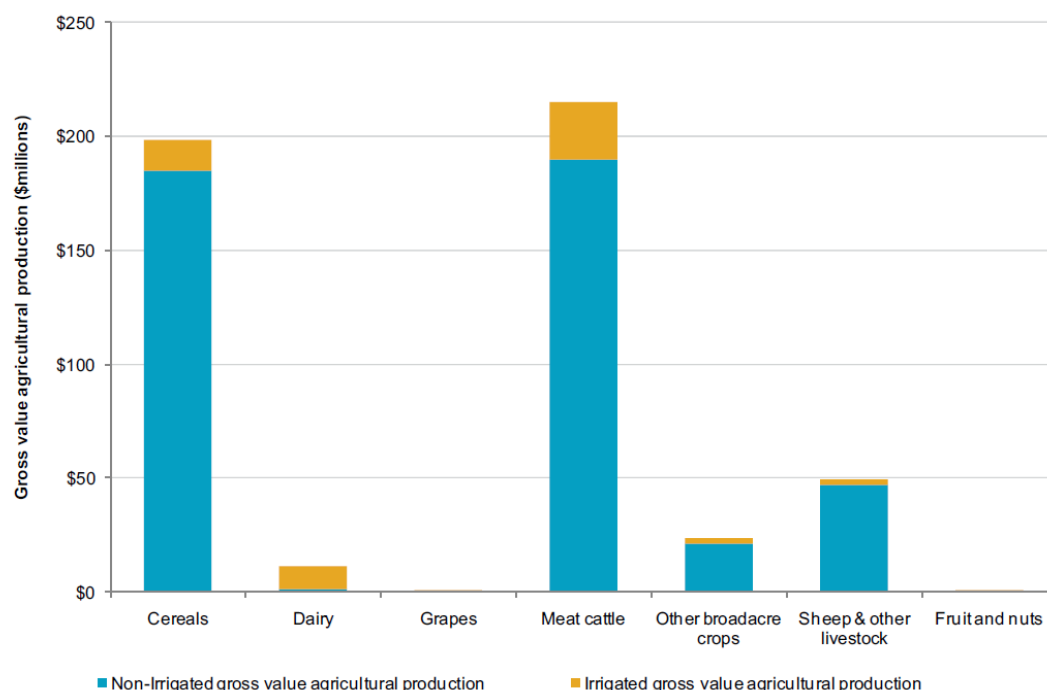


Figure 2. Gross value of agricultural production 2006¹⁹⁸.

In the Namoi Valley, cotton typically accounts for 70 to 80% of farm income while in any one year it might account for as little as 10% of the farm area. The rest of the farm is typically taken up with other crops, crop fallow areas, pastures, roads, irrigation channels, dams and native vegetation. Wheat, sorghum and beef cattle are often part of the enterprise mix (Murray-Darling Basin Authority 2010).

¹⁹⁸ Source: Murray-Darling Basin Authority 2010, ‘Lower Balonne Community Profile’, in *Appendix C of The Guide to the Proposed Basin Plan*, Murray-Darling Basin Authority, Canberra. P. 952

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

Cotton is an expanding industry around Gunnedah; there are over 60,000 hectares of cotton grown in the Namoi Valley and 7 cotton gins, mainly operated by Namoi Cotton.

Implications

Gunnedah's history reveals a town that has had a relatively diverse and dynamic economy, both within and outside of the agricultural sector. Despite long term population growth, in recent times Gunnedah has experienced major economic changes, including drought and the closure of the local abattoir and mine, which have led to the town experiencing large employment losses and economic downturn compared to the rest of the Namoi (Schofield & Ferguson 2005).

Like St George, a major part of the total value of Gunnedah's agricultural output is in cotton, the production of which can be highly variable. However, Gunnedah has a more diverse agricultural base, more reliable irrigation water and is less isolated from larger population centres (for example, Tamworth is only 100 km away). The fertile soils and groundwater supply support a very large livestock industry, as well as summer and winter cropping including wheat, barley, canola and cotton. Greater proportions of labour in industries such as retail trade, education, professional services and manufacturing also mean that the overall impacts of drought on population and employment are softened.

Similar to St George, Gunnedah shire has a high proportion of managers in its agricultural employment base (70%), and there is even less flow-on to labouring than in St George. Businesses are predominantly small, with no businesses in agriculture in 2006 employing more than 20 people.

Appendix 20. Resilience indicators based on critical thresholds

Scale	Threshold	Controlling variable	Potential indicators	
			Direct	Surrogate
National	R&D investment	Level of investment in R&D (sufficient to maintain farm/region/industry viability)	Amount of funds invested in R&D	Research effectiveness in terms of adoption of research outcomes and translation of the science into yield and associated profitability.
	Social license	Socio-political support (public perception) for cotton growing (as a determinant of regulation)	Public perception of cotton production	Positive and/or negative changes in the regulatory framework
	Network connectivity and function	Connectivity Function	Network participation - Efficiency of information flow - Effectiveness of information flow Network structure (number of nodes)	Adoption of Industry best practice and innovation (along with source info identified)
Regional	Network connectivity and function	Connectivity Function	Network participation - Efficiency of information flow - Effectiveness of information flow	Adoption of BMP (along with source of BMP info identified)
	Infrastructure investment	Return on investment in regional infrastructure	Funds invested in new or maintenance of regional infrastructure	
	Vegetation cover	Regional Vegetation Cover	% native vegetation cover	Species diversity and trends
	Water quantity	Regional water availability	% water available for agriculture (as % of total catchment water availability)	Long term rainfall trends
	Land availability	Land use value for alternatives Social licence (public preferences)	Area of land available for cotton production. This could be further differentiated into irrigated/dryland	Land value (i.e. value for cotton production versus other potential land uses such as mining)

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

Scale	Threshold	Controlling variable	Potential indicators	
			Direct	Surrogate
Farm	Water quantity	Groundwater - recharge (governed by rainfall and land use) and extraction rate. Surface water - rainfall	ML water available for cotton production	Long-term climate and rainfall trends including significant rainfall events critical for groundwater recharge.
	Water Quality	Total water volume available from all sources (flow for surface water, access for groundwater)	Level of major water quality contaminants where production is impacted/toxicity - salt - nutrients contaminants/pollutants	Concentrations of major water quality measures
	Soil health	Soil carbon	Amount of soil carbon in cotton growing areas	Groundcover
	Profitability	Debt:income ratio on farm	Farm financial records of debt:income ratio	Regional average Farm Gross Margin (Farm Cash Income less all costs)
	Habitat proximity	Patch size Configuration	Spatial relationship between native vegetation and production areas	Total native veg cover at farm scale

Appendix 21. General resilience indicators

General resilience attributes	Measures and examples of this attribute	Potential indicators	
		Direct	Surrogate
Capacity to self-organise	Social networks Organisational skills and capacity Leadership Trust	% grower actively participating in networks education levels (growers and wider community % growers participating in skills development training Number of events/activities where growers can exchange information and experience (e.g. energy efficiency, WUE, Chemical use, biosecurity & biodiversity management) Proportion of businesses with a farm business plan or succession plan	Regional engagement in cotton industry
Capacity to respond to short term crisis	Support networks Access to reserves of capital Clear roles and responsibilities Memory and experience of past events Training opportunities and pre planning	Liquidity – farm assets/liabilities and farm working capital from cotton industry survey data Evidence of documentation and sharing of experience within and between regions Number of training opportunities for weed/pest surveillance, chemical training, Workplace health and safety etc	Social capital measures (e.g. through Regional Wellbeing Survey)
Capacity to make change at the appropriate scale and time (power, influence and agency)	Suitable governance and institutional arrangements that allow flexible and adaptive approaches, at the right scale Deliberate learning approaches	Resources invested in lobbying/communication (% of investment in capacity building for networking, governance, leadership and advocacy i.e. not R&D) Farm debt levels – overall solvency (i.e. debt/assets ratio from cotton industry data)	-

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

General resilience attributes	Measures and examples of this attribute	Potential indicators	
		Direct	Surrogate
Capacity to innovate	Support for R&D Transfer of new knowledge and skills Learning from practice Immigration of people, technology and skills and capital Support for innovation	Resources for R&D and evidence support for that to continue- Evidence of growers' capacity to influence R&D priorities and influence communication Number of events/activities where growers can exchange information and experience Farm profitability e.g. return on assets or equity	Farm/regional scale reduction in water/pesticide use etc
Diversity	Business types – corporate, family, size Approaches, ideas and innovations Income and livelihoods Ecosystems, land types and soil types	Diversity is a broad concept so requires further definition to allow identification of potential indicators. Share of cotton in farm income – and spread of this at regional scale (from cotton industry statistics) Regional agricultural diversity (i.e. measures of contribution to regional agriculture from different crops and livestock which increases resilience). Regional economic resilience (i.e. industry diversity as less reliance on individual industries increases resilience) Diversity of management responses to control biosecurity risks	Geographic diversity (as a surrogate for climate, soil type, etc) Business size or type diversity (as a surrogate for diversity of financial circumstances from private to corporate etc) Social diversity (e.g. age, education levels)

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

General resilience attributes	Measures and examples of this attribute	Potential indicators	
		Direct	Surrogate
Degree of overlaps (positive redundancy)	Overlaps between institutions and organisations (i.e. some cross membership, shared responsibilities and roles) Shared understanding and mental models of dynamics, risks	Social and institutional network map to identify key individuals and overlapping roles – The indicator would be the average number of links of organisations and people and changes in those over time	-
Modularity	Degree of connectivity which enables or hinders the transmission of shocks through the industry, measured by the ease with which disease or weeds, or new farming techniques, could be spread.	Rate of change in network connectivity – would require periodic monitoring/tracking of key ‘mobile’ elements within the system – contractors, advisors, machinery, to understand degree of interconnection	Trends in number and diversity of contractors over time over the geographic range of interest (farm, region and industry)

Appendix 22. Sustainability indicators¹⁹⁹

The following sustainability indicators were developed by Cotton Australia and CRDC to:

- demonstrate economic, environmental and social credibility to supply chain markets, government and policy makers and community (domestically and globally)
- guide research priorities and investment to enable practice change
- evaluate outcomes of research investments
- benchmark current performance trends over time at the farm and industry scale
- inform and respond to policy development

The indicators cover economic, environmental and social aspects of the cotton industry as outlined in the following table. These indicators are reported on annually as part of the Australian cotton industry's sustainability reports.

KEY ASPECT	ECONOMIC INDICATOR
Cotton industry production statistics	1. Planted area (ha) - Irrigated
	2. Planted area (ha) - Dryland
	3. Yield (bales / ha) - Irrigated
	4. Yield (bales / ha) - Dryland
	5. Fibre quality
	6. Metric tonnes of cotton produced
	7. Grower numbers
	8. Average / median farm size
Economic value	9. Cotton price / bale
	10. Gross value of the cotton produced in Australia (\$)
	11. Cotton exports
	12. Cotton's % of region gross value
	13. Australia's % share of global cotton lint trade
	14. Cotton proportion of global textile market
Profitability	15. Gross margin / ha
	16. Income / ML water

¹⁹⁹ Cotton Australia and Australian Government Cotton Research and Development Corporation 2014. *Australian Grown Cotton Sustainability Report*.

Resilience Assessment of the Australian Cotton Industry at Multiple Scales

KEY ASPECT	ENVIRONMENTAL INDICATOR
Soil health	1. Organic carbon %
	2. Practice change.
	3. Soil sodicity
On farm water use efficiency and productivity	4. Gross Production Water Use Index
	5. Irrigation Water Use Index
	6. Practice change
	7. Whole farm water use efficiency (%)
Groundwater	8. Groundwater levels
	9. Groundwater quality
Biodiversity / riparian	10. Area of native vegetation managed under best practice
	11. Vegetation condition and connectivity
IPM	12. Growers using integrated pest management practices
Chemical use	13. Herbicide use
	14. Insecticide use
GHG emissions	15. Energy use
	16. Nitrogen use efficiency

KEY ASPECT	SOCIAL INDICATOR
Education	1. Highest post school qualification of cotton growers
Employment	2. Number of people employed on farms
	3. Number of people employed - industry
	4. Number of people employed - regional
Workplace health and safety	5. Workers receiving regular health and safety training
	6. Workers health & safety programs in place
Demographics	7. Grower age
	8. Gender participation in industry
Social capital	9. Australian Cotton Conference delegate numbers
	10. Financial membership in regional Cotton Grower Associations
Innovation	11. Investment levels in R&D
	12. Growers adoption of technologies
Legal compliance & responsibility	13. Fines imposed upon cotton SMEs by regulatory authorities