An Impact Assessment of CRDC Sustainability Investments: April 2012 to June 2017

Final Report
To

The Cotton Research and Development Corporation

Agtrans Research

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Acknowledgments

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Abbreviations

ABS	Australian Bureau of Statistics
BCR	Benefit-Cost Ratio
BMP	Best Management Practice
BRG	Border Rivers-Gwydir
CFI	Carbon Farming Initiative
CBA	Cost-Benefit Analysis
CMA	Catchment Management Authority
CO2	Carbon Dioxide
CRC	Cooperative Research Centre
CRDC	Cotton Research and Development Corporation
CRRDC	Council of Rural Research and Development Corporations
CSG	Coal Seam Gas
CSIRO	Commonwealth Scientific and Industrial Research Organisation
D&D	Development and Delivery
DAWR	Department of Agriculture and Water Resources
GDP	Gross Domestic Product
ha	Hectare
IPM	Integrated Pest Management
IRR	Internal Rate of Return
MDB	Murray-Darling Basin
MIRR	Modified Internal Rate of Return
myBMP	myBMP is the cotton industry's best management practice assurance mechanism for growers
NPV	Net Present Value
NRM	Natural Resource Management
NSW DPI	New South Wales Department of Primary Industries
PVB	Present Value of Benefits
PVC	Present Value of Costs
R&D	Research and Development
RD&E	Research, Development and Extension
RDC	Research and Development Corporation
RLF	Regional Landcare Facilitator
WCM	Walloon Coal Measure

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Executive Summary

The Investment
This report presents the results of an impact assessment of a cluster of six sustainability projects funded by the Cotton Research and Development Corporation (CRDC) over the years ending June 2012 to 2017. In addition to CRDC funding (a combination of statutory levies paid by industry participants and matching Commonwealth funding), other resources were provided by research organisation contributions.

Methods
The six individual projects were first analysed qualitatively within a logical framework that considered project rationale, objectives, activities/outputs, outcomes, and impacts. Project Principal Investigators made comments on, and further inputs to, these logical frameworks. Some of the impacts identified through this process were then valued in financial terms. Benefits were estimated for a range of time frames up to 30 years from the year of last investment (2016/17). Past and future cash flows, expressed in 2016/17 $ terms, were discounted to the year 2016/17 using a discount rate of 5% to estimate investment criteria. Investment criteria reported included Present Value of Benefits, Present Value of Costs, Net Present Value, Benefit-Cost Ratio, Internal Rate of Return, and the Modified Internal Rate of Return.

Impacts
Most the impacts identified were economic in nature, however some social and environmental impacts also were identified. Some, but not all, of the impacts identified were then valued in monetary terms. The decision not to value certain impacts was made based on a range of factors including the difficulty linking some project outcomes to impacts, a shortage of evidence to fully support the impact, or a high degree of uncertainty limiting reasonably accurate valuation. The impacts valued are deemed to represent a conservative estimate of the value of the principal benefits derived from the cluster investment.

It is expected that the Australian cotton growing industry will be a primary beneficiary of the investment, as will the natural resource environment. Spill-over benefits to regional communities and to other cropping industries will occur.

Investment Criteria
Total funding from all sources for all six projects totalled $4.85 million (present value terms). The benefits from the investment were valued at $12.26 million (present value terms). This gave a Net Present Value of $7.4 million, a Benefit-Cost Ratio of 2.5 to 1, an Internal Rate of Return of 15.4% and a Modified Internal Rate of Return of 9.1%.

1. Introduction

Background to Impact Assessment

In calendar 2016 and 2017 the Cotton Research and Development Corporation (CRDC) has been carrying out a series of impact assessments of some of their principal Research, Development and Extension (RD&E) investments. The primary purpose of these impact assessments is to assist with portfolio management and provide accountability to the CRDC Board, its levy paying industry and the Australian Government. The results of the impact assessments can also can be used as inputs into the development and/or assessments of further research investments in a sustainability context.

A further purpose of the CRDC impact assessments is potentially to contribute to a process being undertaken by the Council of Rural Research & Development Corporations (CRRDC). This process aims to demonstrate the impacts and their value that have emerged or are likely to emerge from the 15 Rural Research and Development Corporations (RDCs) including producer-owned companies. Valuation of these impacts, along with identification of investment expenditure, is required to demonstrate the RDCs' contribution to Australian rural industry as well as environmental and social impacts to Australia.

The following impact assessment addresses investment by CRDC in a cluster six sustainability projects.

The Importance of Sustainability Research

Sustainability can be defined as a measure of a cropping system's capacity to sustain itself in the long-term without destroying its natural resource base. This has implications not only to maintain or increase the system's productivity over time by enhancing or protecting its productive resource base (e.g. soil, vegetation, water quality and biodiversity) but also by demonstrating its responsibility as an industry sector to other parts of the community. This is particularly important to the cotton industry as it is a relatively intensive cropping industry and uses significant amounts of water and chemicals.

2. Methods

The evaluation approach follows general evaluation guidelines that are now well entrenched within the Australian primary industry research sector including RDCs, Cooperative Research Centres (CRCs) and some Universities. The impact assessment uses Cost-Benefit Analysis. This entails both qualitative and quantitative approaches that are in accord with the impact assessment guidelines of the CRRDC (CRRDC, 2014).

The assessment process commenced with the identification and a brief description of each of the six projects in terms of their objectives, activities and outputs, outcomes, and impacts. The individual project outcomes and impacts were then integrated and described at the aggregate cluster level. The principal economic, environmental and social impacts at the cluster level were then summarised in a triple bottom line table.

Some, but not all, of the impacts identified were then valued in monetary terms. The decision not to value certain impacts was made based on a range of factors including the difficulty linking some project outcomes to impacts, a shortage of evidence to fully support the impact, or a high degree of uncertainty limiting reasonably accurate valuation. The impacts valued are deemed to represent a conservative estimate of the value of the principal benefits derived from the cluster investment.

These benefits valued were then compared with the investment costs for all projects. This allowed aggregate investment criteria to be produced for the investment in the cluster of the six sustainability projects.

3. Description of Projects

Table 1 provides a list of the project codes and titles of all six projects defined in the population of the Sustainability Cluster.

Table 1: Projects Included in the Population of the Sustainability Cluster

Project Code	Project Title
UNE 1201	Positioning growers to take advantage of future ecosystem service markets
CFOC 1303	Regional Landcare Facilitator Moree
GU 1401	Critical thresholds for riparian vegetation regeneration in the northern MDB
UNSW 1401	Quantifying the uncertainty associated with predicting CSG production impacts
RRR 1403	Integrated economic, environmental and social performance reporting of the cotton industry
CRDC 1502	Resilience assessment of the Australian Cotton Industry at multiple sites

A full description of each of the six projects is presented in Tables 2 to 7. The projects are summarised in a logical framework format (rationale, objectives, activities and outputs, outcomes and impacts).

Table 2: Logical Framework for Project UNE 1201

UNE 1201: Positioning growers to take advantage of future ecosystem service markets	
Project Details	Research Organisation: University of New England Period: April 2012 to July 2015 Principal Investigator: Rhiannon Smith
Rationale	It was recognised that ecosystem services provided by native vegetation on cotton farms can benefit the wider community as well as contribute to profitability of cotton production by way of attracting incentive payments to growers that can supply such services. However, many cotton growers are unaware of the potential of their native vegetation resource and how it may be better managed to deliver such ecosystem services and capture associated income payments. In addition, improved management of the vegetation resource on a cotton farm may directly benefit cotton production via impacts on weed and pest control. The Principal Investigator was already familiar with the cotton industry and its ability to deliver multiple ecosystem services in varying ecosystems that would be valued by the wider community. These previous studies focused on three ecosystem services: carbon storage, erosion mitigation, and biodiversity conservation in five native vegetation types common to the lower Namoi River floodplain. These continued to be the focus of Project UNE 1201. A need was recognised to extend the findings of the previous studies to be more relevant and useful to cotton growers. This need included the development of general relationships between vegetation structure, composition and condition to predict ecosystem service provision and impacts. The general relationships then needed to be converted into specific tools for the cotton producer to use so that they could assess management decisions to deliver ecosystem services and potentially gain income payments from existing vegetation or revegetation strategies.
Objectives	The primary objectives of the project were: 1. To quantify some of the key services generated by native vegetation on cotton farms. 2. To calculate the value of different vegetation communities for ecosystem service provision and determine the impact of management on service provision.

Activities and Outputs	• The first objective above was addressed by gathering data from various sources including literature and field trips (including landholder interviews) on:
	  o how the vegetation types across the industry varied from those identified in the earlier study in the Namoi Valley (especially regarding native vegetation, natural wetlands and river and creek frontages),
	  o whether the ecosystem services provided by vegetation in the Namoi Valley were similar in other regions and vegetation types,
	  o how the previous vegetation condition assessment needed to be modified for other vegetation and soil types,
	  o how grazing and other management practices influence carbon storage and other services,
	  o how ecosystem service provision varies over time,
	• Relevant data on the above information needs were assembled from sites across the cotton growing areas, and
	• Representative data assembled addressed soil and vegetation types and their characteristics including carbon storage, erosion mitigation and biodiversity conservation services and their interaction with management of different vegetation types.
	• Many cotton farms were observed to have river or creek frontages and associated areas of riparian vegetation including casuarina, river red gum and coolabah woodland; these species were valuable for providing ecosystem services including carbon storage, erosion mitigation and biodiversity conservation.
	• For carbon storage, river red gum vegetation was the most valuable for carbon storage with total site carbon averaging 216 tonnes per ha compared to grassland with 40 tonnes per ha.
	• For erosion mitigation, the abundance of carbon (and carbon to nitrogen ratios in riparian areas) also supported greater soil protection via increased soil macro-aggregate stability from eucalypt litter and coarse wood debris; however, this could be offset to some extent by high grazing pressure and vegetation loss if not managed appropriately.
	• For biodiversity conservation, riparian areas were found to supply important habitats for a range of plants, birds, micro-bats and beneficial invertebrates so providing ecosystem services such as water filtration, nutrient cycling, pollination and natural pest control; all of these services contributed to the economics of cotton production, as well as the more visible public benefits from biodiversity conservation.
	• Surveys of birds and other fauna and their prevalence were conducted across a range of sites.
	• The data from the above surveys and specific sites were assembled and analysed for various soil attributes including soil carbon, nitrogen and aggregate stability, vegetation types, and bird species.
	• A survey of land management practices (including management of native vegetation) was undertaken and data analysed.
	• A report was produced on the potential causes of river red gum dieback by using tissue sampling, soil sampling, water sampling and groundwater sampling for trees with different degrees of dieback.
	• Once these data were assembled, the second objective required the data to be interpreted and assembled into online databases and tools for growers in specific regions and with specific vegetation types to access and use in assessing different strategies.
	• All the data collected from the project are now held in electronic (Excel) files and, where applicable, hard copy data sheets. Data contained in databases (for all sites sampled) include (Rhiannon Smith, pers. comm., July 2017):
	  o Site details - GPS site location, farm, owner/contact details, vegetation type, bioregion, surrounding land use, catchment, climate data for closest gauge, etc.
	  o Floristic data from two survey periods (Spring 2012 and Spring 2014).

- Vegetation condition data (canopy, shrub, litter, ground cover, presence of tree hollows, distance from water, etc.) at two scales (overall site condition, and measurements within each site).
- Site carbon data, i.e. live woody biomass, herbaceous biomass, litter, coarse woody debris, dead-standing trees, etc.
- Soil data – soil type, %C and %N content.
- Water stable aggregation data (i.e. aggregate stability) for up to eight soil cores collected at each site under different cover types.
- Bird survey data from two surveys conducted by independent observers, species richness and diversity indices, rare and exotic species.

- A very small percentage of sites were lost during the 3.5-year study period as they were cleared or otherwise disturbed.
- For the tools to be relevant, they needed to be connected to existing markets and provide growers with information that would allow them to respond to opportunities as they arose. Tools were therefore aligned to markets as well as supported by an extensive database of relevant data that could be required in future (Rhiannon Smith, pers. comm., July 2017).
- Unfortunately, the hope that emerging ecosystem service markets could be serviced by the project has still largely not come to fruition and there is little current use for the depth of data produced by the project in that regard. However, the project assembled a significant amount of data covering a broad spatial area and in sufficient detail that would prove useful for growers if emerging markets develop in future (Rhiannon Smith, pers. comm., July 2017).
- The project contributed to a range of initiatives (e.g. UQ [carbon], CSIRO [pest suppressive landscapes], local CMA/LLS/Landcare initiatives, etc.) to piggyback project messages on tools from other projects.
- The project concentrated on science and data aspects to provide scientifically sound (peer-reviewed) data and messages to growers and the industry.
- The project was involved in many field days and discussions with growers and extension staff to communicate messages from the project; this was viewed as a more productive communication approach than developing specific tools for non-existing market based incentives.

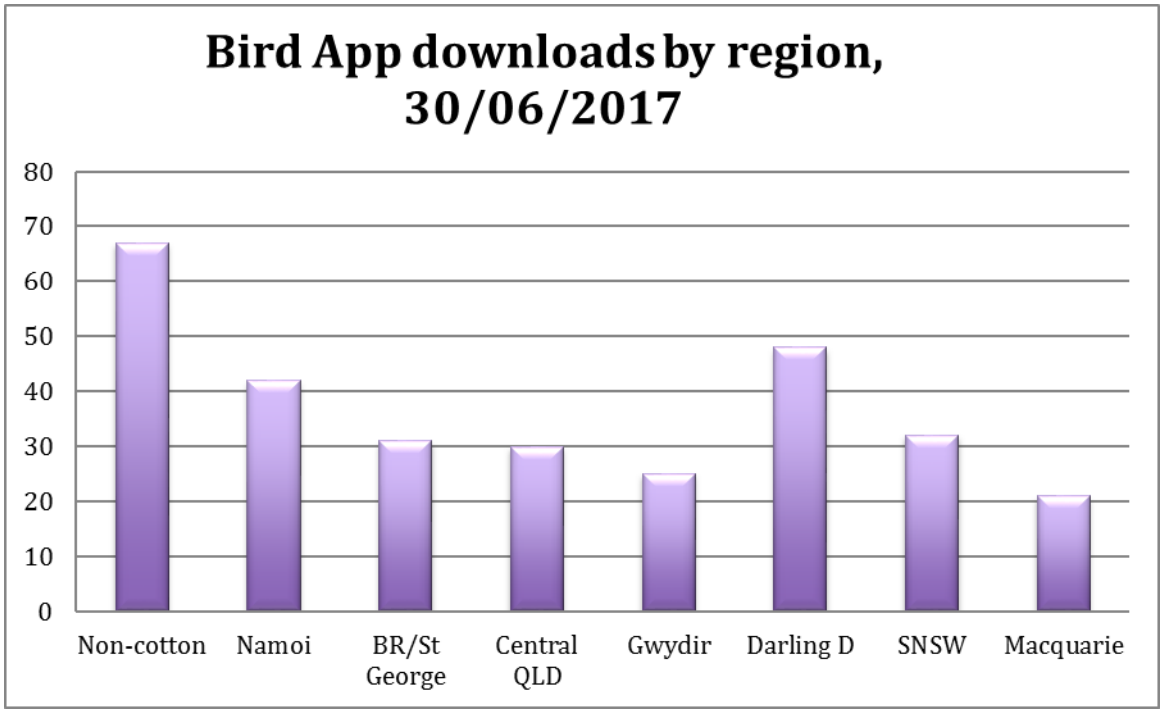
<u>Specific target market outputs</u>

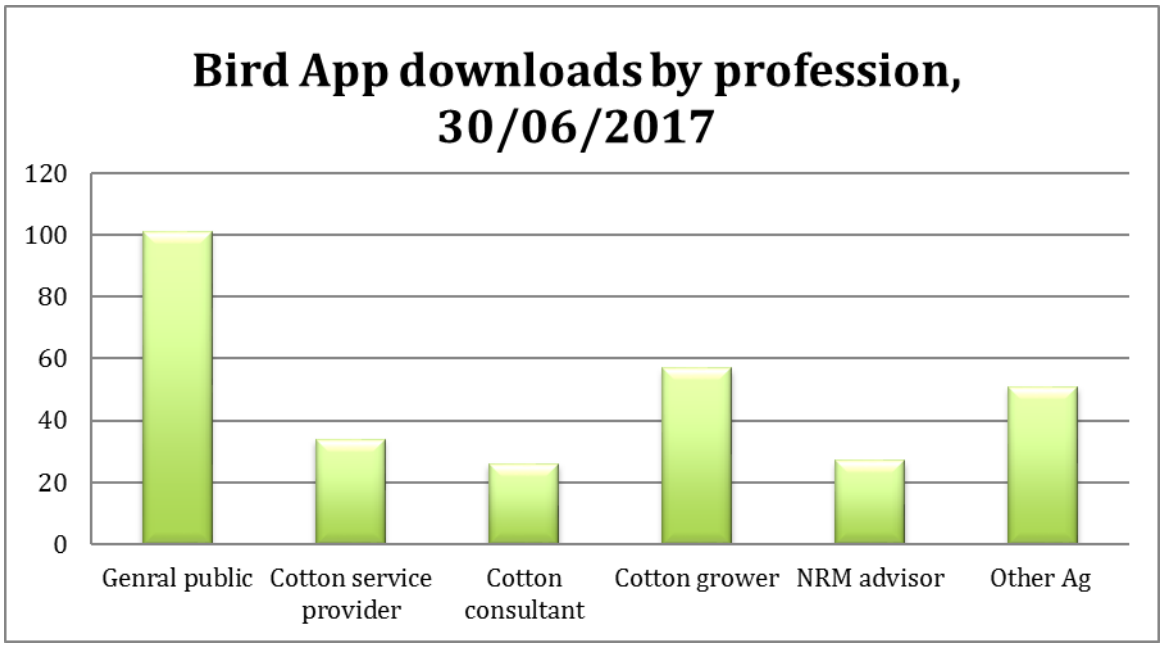
Carbon market:

- The project's carbon sequestration data were incorporated into the carbon calculator tool being developed at the University of Queensland. Applications from two case studies showed that cotton farms could be carbon neutral when carbon sequestration by native vegetation was taken into account.
- Two significant journal papers and a conference presentation and associated proceedings paper were produced in this component of the project (Rhiannon Smith, pers. comm., July 2017).
- The first paper illustrated the value of native vegetation for storing carbon in different vegetation components and vegetation communities across the Namoi Valley. This paper showed the important service cotton growers are providing in protecting considerable carbon stores in remnant vegetation (particularly riparian vegetation) on their properties.
- The second paper showed carbon sequestration rates by riparian vegetation (river red gums in particular) on cotton farms across the Namoi Valley (during La Niña conditions) rivalled growth and sequestration rates in tropical forests in some instances, and provided evidence to kick off conversations about the potential inclusion of a riparian vegetation protection and management methodology under the Emissions Reduction Fund (ERF), thus opening up a potential market in which cotton growers could participate.

Biodiversity and biodiversity offset markets:

- There are few formal options for biodiversity offsets that attract payments (BioBanking in NSW being the exception).
- The bird survey data collected in the project was used to inform the update of the 'Birds on Cotton Farms' app. that was presented at Goondiwindi towards the end of the project.
- As at June 2017, the Birds on Cotton Farm app. has had 296 downloads of which over 200 were in cotton growing regions. There have been 193 individual bird sightings recorded using the app.'s monitoring tool by 60 unique users. Below are two graphs showing some demographic data on who is downloading the app and from which regions (Source: Stacey Vogel, pers. comm., July 2017).





	• Species lists of birds recorded at various sites were sent to the respective managers/owners that were interested, for their own birding records. • There were a number of threatened and declining species of birds recorded during the surveys with such data providing a good news story for the cotton industry. • Biodiversity data were used to support modelling to inform market-based incentives to growers to provide habitat for biodiversity (and in turn, benefit from a range of ecosystem services provided by biodiversity, including natural pest control, erosion mitigation, etc.). These data continue to be published and used to develop general 'rules-of-thumb' for growers. • It was concluded that biodiversity value based on modelling tools and predictions of species occurrences utilising satellite-derived data on vegetation extent, connectivity and condition (which are often used as part of the assessment of biodiversity value for schemes such as BioBanking) do not align well with the real-world data; greater numbers and species of threatened/endangered/declining birds were found than the models predicted would be found; hence the link between satellite-derived models, and species presence and abundance on the ground may be tenuous, particularly in agricultural landscapes. • There is a need for the project data to be published so that these links can be further explored and improved. In many instances, there is not enough data available on the majority of threatened species in agricultural regions, particularly on private land, to predict (a) where different species exist and (b) how they move around and use different parts of the landscape at different times (Rhiannon Smith, pers. comm., July 2017).
Outcomes	• The project developed an innovative approach to environmental stewardship that should prove of current and significant future value to cotton producers and the cotton industry. • Evidence of significant and widespread native vegetation management changes by cotton growers due to the project is not available; some changes made by growers are likely to have been driven by other natural resource management (NRM) research as well as by this project. • Some of the outcomes of the project relating to specific growers and reported by Rhiannon Smith (pers. comm., July 2017) include: o The project staff have been approached by several growers across the industry to have carbon accounting assessments done across their properties. o It is believed that a handful of growers have projects under the ERF (although the details of these projects are not known and may not be related to native vegetation management). o The project team has worked with a grower at Boggabri who has allowed access to his yield and profitability data to investigate links between the revegetation carried out and his production figures (e.g. the natural pest control service provided by biodiversity within his tree plantings). o A grower group has approached the project team to effect biodiversity assessments on their cotton farms. o Several growers have voiced concerns around tree dieback and have sought information on the causes of ill health in their trees, and the impacts this may be having on biodiversity and other ecosystem services, as well as their social licence to farm. These growers have changed spray regimes (chemicals and timing of sprays) to minimise impacts on both native and planted vegetation after conversations with the project team. o A grower near Emerald provided data from past biodiversity surveys conducted on his property. o A group of growers near Emerald (working with Liz Alexander, and having conversations with Nancy Schellhorn and Rhiannon Smith) have launched an innovative approach to valuing native vegetation for ecosystem service provision. o A grower from Goondiwindi has actively excluded stock from his riparian areas after hearing the Cotton Production Course Lectures.

	○ A grower near Merah North excluded livestock from a 500 ha paddock occupied by an Endangered Ecological Community for five years to improve biodiversity. He has also established areas on his property for the sole purpose of biodiversity conservation. ○ A number of growers have installed nest boxes to encourage microbats onto their farms for natural pest control after talking to project staff. ○ A grower near Bellata signed up to the Federal Government Environmental Stewardship Programme in the early days of the project. ○ Several growers have changed spraying practices to minimise impacts on trees and beneficial insects in the Namoi and Gwydir catchments. • Many of the vegetation communities with whom the project worked are listed as Endangered Ecological Communities under state and federal-level biodiversity legislation. At the commencement of the project, several of these communities were eligible for payments under the Federal Government's Environmental Stewardship Programme (http://www.nrm.gov.au/national/continuing-investment/environmental-stewardship). Unfortunately, with the change of Government, this scheme did not continue. One grower near Moree did get involved in this scheme and the project provided data to that grower to support the annual reporting for that site (Rhiannon Smith, pers. comm., July 2017). • In NSW, the BioBanking scheme may provide an opportunity for growers to gain funds through biodiversity offsets. However, the viability of this scheme is under threat due to changes in assessment criteria and planning legislation. Feedback from growers involved in Project UNE 1201 indicated that there would be little interest in this scheme, as it involves covenants to be established on the land title and restrictions on use and management to meet the 'maintain or improve' criteria. Many growers would rather do their own thing and conserve biodiversity under their own terms (Rhiannon Smith, pers. comm., July 2017). • Few growers have participated in reverse auction schemes to deliver ecosystem services as a result of Project UNE 1201. An exception is the grower at Bellata (see above) that now has covenants on areas of her property under the Environmental Stewardship Programme. • In the experience of the project, few growers publicise their participation in such schemes and many are hesitant to sign up due to restrictions imposed on land use and management, and the associated paperwork involved in participating in these types of schemes. However, several growers have signed up to co-funded projects, particularly around riparian management and tree planting with their local Catchment Management Agency (Rhiannon Smith, pers. comm., July 2017). Extension and communication: • The project promoted good news NRM stories across the industry in the NRM space; this promotion carries much significance due to the Principal Investigator's status in scientific and policy circles. • The project interacted strongly with Catchment Management Authorities and the community (e.g. via inputs to university courses etc). • Various scientific papers, conference presentations, and industry communications were published and/or presented. • The project staff were in constant regular contact with Stacey Vogel, Jon Welsh and others at CottonInfo to communicate the findings of the project through myBMP and other sources. A review and update of myBMP targets was conducted early on during the project and project personnel participated in, and contributed to, that process as well as participating in field days promoting myBMP and NRM practices. Potential policy development:

	• The project findings could have significant implications for policy development to address target markets. Currently, there is no market for carbon stored or sequestered by remnant/old growth vegetation, and models predicting carbon sequestration in the areas occupied by cotton production in Australia severely underestimate the value of remnant/old growth vegetation, particularly riparian vegetation, for sequestering carbon (Rhiannon Smith, pers. comm., July 2017). • The project approach was to provide hard evidence of the potential value of these areas of native vegetation on cotton farms, particularly riparian vegetation, for sequestering and storing large amounts of carbon. In particular, the project aspired to (Rhiannon Smith, pers. comm., July 2017): o provide ammunition for the development of a methodology under the Emissions Reduction Fund, o ensure recognition of the value of remnant/old growth vegetation and the environmental service growers are providing by protecting that vegetation resource, o stress the need for payments to growers through an innovative environmental stewardship scheme targeting vegetation protection for multiple benefits, including biodiversity conservation and carbon storage, and o provide access to markets targeting carbon conscious consumers looking for carbon neutral carbon that may be integrated into marketing for existing programmes such as the Better Cotton Initiative (BCI), Cotton LEADS or myBMP.
Impacts	• Contribution to improved management of native vegetation and riparian areas by cotton growers that may have increased carbon storage, reduced erosion and soil loss, and enhanced biodiversity. • Potential increases in future profits from cotton production directly via additional income from incentive payment schemes based on well-managed riparian areas. • Increases in profits from cotton production indirectly via potential pest control and pollination enhancement. • Reduction in cotton farm production costs as a result of avoided expenditure (e.g. erosion mitigation). • Increases in cotton prices as a result of access to markets targeting environmentally conscious consumers. • Contribution to lowered risk of a loss of the cotton industry's social licence to operate.

Table 3: Logical Framework for Project CFOC 1303

CFOC 1303: Regional Landcare Facilitator Moree	
Project Details	Research Organisation: Gwydir Valley Irrigators Association Period: July 2012 to September 2013 Principal Investigator: Lou Gall
Background and Rationale	The project supported for one year a full-time Regional Landcare Facilitator (RLF) based at Moree. The RLF position had been funded already for two years and was located within the Gwydir Valley Irrigators Association. Funding was already in place for this third year from the Cotton Catchment Communities CRC, Border Rivers Gwydir (BRG) Catchment Management Authority (CMA) and via New England North West Landcare. The project was to build on the existing networks of growers, consultants and agronomists already created by the RLF at Moree.
Objectives	1. To achieve the relevant targets as the Regional Landcare Facilitator for Moree. 2. To achieve the relevant targets for the Cotton CRC's Caring for Our Country project in the Border Rivers Gwydir Catchments. 3. To transfer information to the cotton industry relating to the Carbon Farming Initiative.

	4. To link Regional Landcare Facilitators in other regions to the cotton industry. In addition: 5. To provide farmers and other landholders with information on the Carbon Farming Initiative (CFI). 6. To act as a regional contact point for landholders seeking information about the CFI.
Activities and Outputs	• The project developed partnerships and joint efforts between landholder groups, service providers (consultants and agronomists) and extension services. • The RLF worked with the 6 area wide management groups across the region (e.g. Rowena and Ashley regarding feral animals and Mungindi regarding biodiversity benchmarking). • Engagement activities included targeted workshops that addressed Integrated Pest Management (IPM), promotion of myBMP and other issues; in addition to workshops, other communication mechanisms were used including direct contact, web based material and webinars. • A total of 155 participants attended field days and workshops across 10 activities. • The overall area covered by the project was of the order of 100,000 ha. • The Moree RLF was part of the Cotton Development and Delivery (D&D) Team and was kept up to date with the CFI. • The RLF acted as a contact point for landholders on the CFI and provided information on how growers could potentially benefit from the CFI. • The biodiversity benchmarking activity (Mungindi group) focused on pests in the landscape and included vegetation assessments on eight sites for four properties involved. The assessments used the Cotton Catchment Communities CRC template and identified species and defined ground cover levels. • At least two publications were produced by the project: (1) A summary document 'Vegetation Condition Assessment for Natural Pest Control on Cotton Farms' (as prepared by Dave Carr of Stringybark Ecological and sent electronically to landholders). (2) The BRG-CMA has printed a booklet prepared by Dave Carr for the Mungindi and Boomi areas of Northern NSW. The booklet will assist growers to identify and better manage native vegetation on their farms. • A Grower Workshop and follow up took place regarding the increasing feral pig populations and the need for control. This lead to 43 individuals engaging in several coordinated pig shoots from helicopters on a regional basis killing over 1,500 pigs during 2012 and 2013. • The shootings were coordinated across land areas and auxiliary baiting and trapping initiatives were also carried out. • The Mungindi biodiversity benchmarking initiative focused on five irrigated properties and included vegetation assessments and the role of natural pest control. • Regarding the CFI, inputs to various applications was provided by the RLF and three CFI activities were carried out including a trade display, a session at the Landcare Adventure and via printed material in the Landcare Update.
Outcomes	• Increased knowledge and skills of IPM and NRM were delivered to growers through workshops and provision of expert knowledge via various means. • Partnerships with BRG-CMA assisted landholders to adopt Best Management Practices (BMPs) that were recorded through their participation in the myBMP initiative. However, there was some reluctance for uptake.

	• Engaging growers in the myBMP initiative (particularly in relation to the Natural Assets module) generated increased adoption of sustainable farm and land management practices. • These changes included increased adoption of stewardship, covenanting, property management plans or other arrangements to improve the environment both on and off farm. • The on-ground component of the project lead to 47 farmers adopting activities that contributed to the conservation and protection of biodiversity and natural pest control across over 114,000 ha of land. • Partnerships between organisations in the Moree Region with those in other regions were strengthened via the national Regional Landcare Network. • The biodiversity assessment lead to over 16,000 ha of land managed with a greater awareness of managing for biodiversity purposes, for example, enhancing native vegetation corridors. • The RLF activities regarding the CFI information may have resulted in some increased awareness of the potential for increasing carbon capture via native vegetation management. However, interest in the CFI was low as exemplified by unused boxes of CFI brochures at the Moree Cotton Trade Show (Lou Gall, pers. comm., June 2017). • The pig shooting activity resulted in feral pig numbers being lowered and their breeding numbers reduced. • A significant reduction was observed in the pig impacts on native vegetation, and farming and grazing operations; the success was attributed to the coordinated approach and the grower ownership of the initiative. • After the project was completed further grants were received to support farmers in the control of feral pigs in 2015/16 (Lou Gall, pers. comm., June 2017). • The success of the project overall has been linked generally to the emphasis on networking, and coordinated landholder engagement in a bottom-up framework and resulting in improved delivery of a range of natural resource management information and protocols.
Impacts	• Increased adoption of BMPs regarding natural resource management and IPM native vegetation management, resulting in some additional carbon storage, reduced erosion, and improved management of biodiversity in native vegetation areas • Enhanced biodiversity and lowered chemical costs on some farm areas. • A reduction in feral animal pig impacts, at least in the short term. • Contribution to the industry's social licence to operate.

Table 4: Logical Framework for Project GU 1401

GU 1401: Critical thresholds for riparian vegetation regeneration in the northern MDB	
Project Details	Research Organisation: Griffith University Period: July 2013 to June 2016 Principal Investigator: Samantha Capon
Background and Rationale	Riparian vegetation is a critical component of inland river landscapes as it strongly supports biodiversity and provides various ecosystem services. Questions had arisen of the resilience of these riparian vegetation communities to hydrological and climate changes to allow improved decisions about vegetation management and regeneration. Such information was regarded as important to guiding the allocation of environmental water that was to become available in the northern Murray Darling Basin (MDB). A case was made that information on regeneration of the

	most dominant structural plants such as trees, shrubs, reeds and perennial rushes was inadequate for management purposes.
Objectives	The broad aim of the project was to predict the outcomes on riparian vegetation of hydrologic changes forecasted under various water management and climate scenarios and thus identify appropriate interventions for protecting, maintaining and restoring species and communities. Specific scientific objectives were: 1. To describe spatial and temporal patterns in mechanisms of vegetation regeneration among key riparian plant species and vegetation communities of the northern MDB and determine major hydrologic, climate and other drivers of these; 2. To identify critical hydrological thresholds (e.g. duration of dry spells) for processes of riparian vegetation regeneration in the northern MDB; and 3. To predict potential shifts in riparian vegetation dynamics of inland riverine landscapes under various hydrologic and climate scenarios. Specific management objectives were: 4. To identify critical locations for regeneration of key riparian plant species and vegetation communities in the northern MDB that may require protection, watering or other management interventions; 5. To contribute to the development of improved guidelines for the acquisition, allocation and monitoring of environmental water in the northern MDB for targets associated with riparian vegetation regeneration; and 6. To provide empirical evidence to support improved monitoring and review of existing and future Water Sharing/Resource Operation Plans within the northern MDB.
Activities and Outputs	• The patterns of riparian vegetation were examined across the northern MDB with an emphasis on the Condamine-Balonne and the Barwon-Darling systems. • Seed dispersal, germination, seedling growth and mortality were examined through field surveys and glasshouse experiments; aerial photography and satellite imagery also were used. • Canopy structure and composition was important for riparian understorey vegetation diversity and dynamics at both local and landscape scales. Hence such factors need to be addressed in land and water management practices associated with riparian vegetation management. • Early in the project initial field trips took place and surveys were undertaken of riparian vegetation and understorey vegetation condition (including habitats, groundcover, lignum, tree types and seedlings) across a large number of sites: riparian tree seedlings were tagged and propagule traps (e.g. for seeds, tubers, runners etc.) were installed at some sites; seeds and soil samples were collected also for later experiments. • Glass house experiments were undertaken to determine the role of local environmental factors on responses of riparian soil seed banks to flooding and the effects of warming (e.g. climate change). • Mesocosm experiments were conducted with the germinable propagule bank contained in riparian soils, litter and animal scats collected earlier in the project. These experiments included such factors as climate and flooding, shading and litter, and their interactions. • It was recognised that stakeholder knowledge was important and collection of such information via informal interviews proceeded together with a later formal survey to assess stakeholder knowledge, values and concerns

	regarding riparian zones; this was seen as important for both learning for the project team and for later landholder engagement purposes. • Further field trips with a focus on further understanding emerging spatial patterns and temporal responses were undertaken. • A glasshouse experiment was undertaken to examine acacia establishment in response to hydrologic factors. • A shift in the project was made towards determining local, farm scale and land management influences (e.g. riparian buffer width, grazing practices) on riparian vegetation changes. • Some field work was undertaken to better understand farm management practices in relation to management of riparian systems, so that any later surveys were more focused. • A survey of management of riparian zones by landholders was planned but not carried out due to lack of respondents and other factors. However, the intent is likely to be pursued in a following CRDC project (GU17017) targeting management of natural ecosystems in cotton landscapes. • A communication strategy was developed and a range of diverse communication products produced. Specific Outputs • Riparian ecosystems in the northern MDB were found to support significant biodiversity with regard to vegetation with over 175 native species recorded in the project. • A synthesis paper on woody riparian vegetation regeneration traits and dynamics was produced. • A description of spatial and temporal patterns was produced with regard to: o riparian habitat characteristics, o riparian plant recruitment and their drivers; o riparian groundcover structure and composition and their drivers. • The glasshouse experiments showed that shade had a positive effect on the abundance, diversity and reproductive capacity of establishing plant communities under dry conditions but negative or no effect under wet conditions; litter had strong negative effects under all hydrological conditions. • Litter, rather than soil was shown to be a more important source of propagules for the regeneration of woody species; litter appeared also to be important for a wide array of understorey species as it has the highest number of species of the seed bank types (e.g. woody species). • Macropods appeared to be an important mechanism for the dispersal of riparian groundcover plants (e.g. perennial grasses). • A finding from the mesocosm experiments was that shade enhances understorey vegetation abundance and richness under drier conditions, while the presence of litter retards emergence of seedling and ultimate abundance and richness under wetter conditions. • Groundcover vegetation appeared highly resilient to environmental changes (e.g. drought), whereas the current regeneration of riparian trees is very low and patchy, especially coolibah and river red gum. • Cattle grazing has a number of undesirable impacts on habitat structure and vegetation regeneration through reduced wood and shrub cover, increases in weeds and bare ground, and lower litter cover. • Early results of the Acacia experiment suggested that *Acacia stenophylla* is extremely tolerant to both flooding and drought, but weeping myall (*Acacia pendula*) is not tolerant of flooding but is resistant to drought.

	• An important suggestion from the project was that environmental flow management should consider the importance of flooding in promoting regeneration. • A range of communication activities and products were undertaken/produced including scientific papers, inputs to scientific review processes, information sheets, notes in newsletters, contributions to magazines, symposia and congresses, and cotton riparian condition and management meetings. • In summary, an improved understanding was developed of how key riparian and plant species and vegetation communities regenerate in the northern MDB.
Outcomes	• The strengthened knowledge regarding the importance of flooding in the distribution and structure of woody riparian vegetation, particularly the positive impact of flooding on establishment of high value Eucalyptus species, will have implications for the management of environmental flows by river authorities. • The findings from the project have contributed to a range of extension activities aimed at cotton growers; these include the development of the Natural Assets module of my BMP, as well as a CRDC associated riparian monitoring program. • Project results may strengthen the recommendation for improved land management of riparian areas by cotton growers resulting in, for example, improved habitat protection, reduced weed incidence, and increased tree regeneration. • There is some anecdotal information about improved awareness and capacity to implement BMP from field days where extension messages on litter for weed suppression were extended. Also, the 2017 Cotton Grower Survey that is currently being undertaken has a question around awareness and current practice for litter/weed suppression but those results are not yet available (Stacey Vogel, pers. comm., 2017).
Impacts	• Improved management of riparian areas on cotton farms may result in improvements in biodiversity and the delivery of other ecosystem services (e.g. carbon storage, reduced erosion and lowered soil loss) from riparian areas. • Changes in improved environmental flow management with regard to flooding may enhance woody thickening and the presence and utility of Eucalyptus species, so increasing biodiversity and long-term carbon capture. • Contribution to the industry's social licence to operate.

Table 5: Logical Framework for Project UNSW 1401

UNSW 1401: Quantifying the uncertainty associated with predicting CSG production impacts	
Project Details	Research Organisation: University of New South Wales Period: July 2013 to June 2016 Principal Investigator: Bryce Kelly
Background and Rationale	The Walloon Coal Measures (WCM) associated with Coal Seam Gas (CSG) extraction will peak at 200,000 ML/year between 2020 and 2025. This hydraulic depressurising will be transferred into the overlying geological formations. The WCM lie within the Surat Basin, a part of the Australian Great Artesian Basin, and lie beneath much of the primary freshwater aquifer (the Condamine Alluvium) used by the cotton industry in the Darling Downs Condamine catchment. A 'make good' agreement between irrigators and the CSG producer included a proposal that, where the groundwater monitoring level should fall by greater than

	2 metres, and it is demonstrated that it is due to CSG production, the CSG producer will make good water supplies for the affected irrigators. In addition, irrigators in the Condamine catchment have had to bear significant reductions in water extraction over the past decade. These reductions have included groundwater and have been in the interests of maintaining the sustainability of the resource for both production purposes and for environmental flows. There are various other factors in addition to CSG extraction and groundwater extraction for irrigation that can influence the groundwater level, including irrigation deep drainage, flood recharge, variable rainfall recharge, and climate variability. The research was required to isolate and assess the potential impact of CSG extraction on groundwater levels. Groundwater chemistry also changes over time. This project aimed to provide updated data sets, which can be used to assess change over the past 50 years of irrigated agriculture. The data sets also provide baseline conditions to enable future assessments of CSG impacts, which will take many decades to become apparent.
Objectives	The broad aims of the project were: 1. To inform policy developments so that best practices are implemented before the CSG production becomes fully established. 2. To provide input into the debate surrounding the CSG "make good" provisions, and provide baseline data to allow quantification of the impact of the expansion of the CSG sector in the Condamine. 3. To map the presence of leaky abandoned coal exploration wells, which act as pathways of connectivity between the coal measures and the overlying alluvial aquifer. Specific objectives were: 1. To quantify and assess the uncertainty of major inputs to groundwater models, which are used to allocate groundwater resources and assess the impact of multiple users, including the CSG and irrigation sectors. 2. To provide the cotton industry and others with: a) Educational material on the impacts of the CSG sector; b) A list of recommendations for improving the surface-water and groundwater monitoring networks for quantifying the impact of the CSG sector; c) A list of issues with existing groundwater policies for attributing changes in groundwater levels to any activity, in particular the irrigation and CSG sectors; d) Baseline groundwater quality measurements; e) Date the age of the groundwater being used by irrigators; f) Baseline gas methane concentrations in the ground level atmosphere; g) Isotope analyses of methane from various sources; these data can be used to attribute source and proportion contribution. h) An assessment of the connectivity between the Condamine Alluvium and the WCM; i) A groundwater flow model that assesses the impact of abandoned leaky wells on water transfers between the Condamine River Alluvial Aquifer and the Walloon Coal Measures.
Activities and Outputs	The major activities undertaken in the Condamine catchment were:

	• Sampling, measuring and analysing baseline groundwater parameters from 30 bores in priority areas in the Condamine Alluvium. This included major ions, isotopes, organics and gas content. • Undertaking measurements of the methane in the ground level atmosphere around coal seam gas developments, coal mines, dryland farming, irrigation farms, feedlots and towns. These data have been incorporated into a Google Earth model, which has been provided to CRDC. Over 4,000 km of surveys were completed. • Building a three-dimensional groundwater flow model to explore: o Baseline groundwater transfer between the WCM and the Condamine alluvium o Groundwater transfer between the WCM and the Condamine alluvium if CSG production drops the groundwater head (level) by 50 m in the WCM. o Water transfer between the Condamine Alluvium and the WCM when an abandoned leaky exploration well is present. • Estimating areal (diffuse) rainfall recharge to the Condamine Alluvium and quantifying the uncertainty of that estimate. • Estimating the likelihood of flood recharge and quantifying its importance to sustainable groundwater use. The measurements and modelling highlighted the need to: • Better map the location of geological faults that underlie the Condamine Alluvium. • Locate and remediate abandoned exploration gas wells to prevent the movement of fluids between strata in areas of CSG development. • Consider the age of the groundwater in future groundwater allocation assessments. • Improve the assessment of flood recharge when allocating groundwater. This can be achieved by linking groundwater chemistry data to the flow modelling; to date this has not been done by any government organisation. • Consider managed aquifer recharge of flood waters to optimise the use of water in the catchment. • Information and findings from the project were disseminated to interested parties via meetings, factsheets, research and development (R&D) updates, water chemistry data sheets (provided to each grower individually with a 1 to 2 hour meeting to discuss the results), a Google Earth display of methane concentration, an article in Spotlight Magazine, articles in “The Conversation”, ABC rural radio interview, ABC rural online news, an article in The Saturday Paper, conference and convention presentations, scientific journal articles (made freely available online), and presentations to Queensland Government Departments. *Maules Creek – subproject* In addition to the above, baseline air and water quality parameters were recorded for the Maules Creek catchment. These included: • Measurement of the groundwater and air methane concentrations in the Maules Creek Catchment. • Preliminary measurements of groundwater isotopes and dissolved organic carbon in the groundwater. From these preliminary measurements in the Maules Creek catchment, no major issues were detected with respect to the parameters measured.
Outcomes	*Condamine Catchment primary outcomes:* • The project has provided independent scientific information on the impacts of the CSG sector on the water resource used by the cotton industry.

	• The project demonstrated to the cotton industry the relative importance of CSG production and irrigation extraction in influencing changes in the measured groundwater levels at a specific location. • The main finding was that the extent of hydraulic connectivity between the WCM and the Condamine Alluvium is low near Cecil Plains. Hence, the project found no immediate concerns associated with CSG impacts on groundwater volumes in the Condamine Alluvium. • Abandoned wells that were leaking gas were located north of Chinchilla. No abandoned leaky gas wells were located within the cotton growing districts near Dalby or Cecil Plains. While most major roads were surveyed, there are many thousands of kilometres of minor road that were not surveyed, so there remains a low risk that there are abandoned leaky exploration wells. • From the groundwater modelling results it is apparent that a single abandoned leaky well will result in significant movement of water from the Condamine Alluvium to the WCM once CSG production has dropped the groundwater head in the WCM. It is recommended that where leaky wells are detected they should be remediated. • The QLD Office of Groundwater Impact Assessment now acknowledge the need to assess the impact of abandoned leaky wells in their groundwater modelling. Such wells will be incorporated into their next model revision. • The project has highlighted that many irrigators in the regions distal to the Condamine River are using groundwater that is many thousands of years old. The use of such water needs to be carefully monitored and managed. • The project has provided information useful in the review of the groundwater allocations of cotton farmers in the upper Condamine. • From the groundwater chemistry, it has been determined that the only time there is significant recharge to the Condamine is after flooding. Sustainable assess to groundwater resources will depend on flood frequency. • The study has also extended the data sets being used to guide government policies on CSG production (e.g. structuring and approval processes). • Personal feedback from the Federal Independent Scientific Committee on Coal Seam Gas and Large Coal Mining Development has indicated that the project results provide important background information, which assists them in their decisions and reporting. They are also constantly monitoring the media and responses, and have noted the impact of this research on community discussions. • Monitoring of web, media citations and journal citations has placed interest in Iverarch et al. (2015) in the top 2% of all articles being tracked world-wide. *Maules Creek – subproject outcomes* A community town hall meeting was held at Maules Creek to update the residents on the ongoing research and findings to date. Preliminary findings for this catchment are: • The dissolved organic carbon and tritium data suggest that for the sites measured, most groundwater users are using modern groundwater < 70 years old. • Gas levels in the groundwater were low and safe. • The concentration of methane in the atmosphere on the days sampled was very close to normal background air.
Impacts	• The project findings may have reduced immediate concerns of cotton irrigators and communities that are dependent on cotton, and may have reduced their stress levels.

	• The project may have given irrigators confidence to invest and to continue negotiations with the Commonwealth Government about water buy backs. • Consideration should be given to managed aquifer recharge during flooding.

Table 6: Logical Framework for Project RRR 1403

RRR 1403: Integrated economic, environmental and social performance reporting of the cotton industry	
Project Details	Research Organisation: Roth Rural and Regional Period: December 2013 to June 2016 Principal Investigator: Guy Roth
Background and Rationale	Sustainability reporting for food and fibre production, driven by consumers and communities, is now well established globally. Roth (2010) produced the first sustainability report on the Australian cotton industry in 2010. Since then various other recommendations in Australia and globally, have stressed the importance of sustainability reporting. For example, the International Cotton Advisory Committee meeting in October 2012 and September 2013 confirmed the importance of sustainability and using evidence based knowledge to demonstrate the sustainability pathway of continuous improvement. One of the prominent reasons for the funding of Project RRR 1403 in 2013 was the recognition that the Australian industry had a significant amount of relevant economic, environmental and social information available, but that it was fragmented in its location as well as in time.
Objectives	The overall aim of the project was to produce a robust framework and publish a report that the cotton industry could use to provide information in relation to the sustainability of cotton production in Australia. The specific principal objectives were: 1. To implement a flexible, robust, credible and efficient system for integrated economic, environmental and social reports using the R&D portfolio of CRDC and other industry data. 2. To develop long-term data sets, make better use of past R&D project data and improve industry knowledge on priority sustainability indicators. 3. To build industry capacity and knowledge across the economic, environmental and social disciplines. 4. To be a national and global leader among rural industries in demonstrating and communicating sustainable cotton value chain practice. 5. To establish future targets to improve the sustainability of Australian grown cotton.
Activities and Outputs	• The previous set of sustainability indicators (Roth 2010) was reviewed and updated by the Australian Cotton Industry's Environmental Assessment working group. • An external stakeholder forum discussed issues as well as provided feedback on sustainability issues. • Significant attention was given to supply chain sustainability initiatives such as the Better Cotton Initiative, Cotton Leads and the Expert Panel on Social, Environmental and Economic Performance of Cotton Production of the International Cotton Advisory Committee. • A long list of more than 100 potential sustainability indicators was developed; each indicator on the long list was scored against six criteria, including materiality to cotton industry stakeholders, materiality to external

	stakeholders, cost effectiveness of data collection, technical difficulty of data collection, data integrity and confidence, and accuracy of the data collected. • Forty-five indicators were short listed as high priorities. • Data were then assembled and analysed from a range of sources relevant to these indicators. • Use was made of the Global Reporting Initiative Guidelines to produce the first Sustainability Report for cotton and for Australian agriculture; this demonstrated both global and Australian leadership in reporting. • The Australian Grown Cotton Sustainability Report was launched and published in late calendar 2014 (CRDC and Cotton Australia, 2014); this report included data sets that were provided to CRDC as the custodian. • Several industry forums discussed the three pillars of sustainability (economic, environmental and social). The forums included a formal external stakeholder leaders' forum in June 2016. • A paper, agreed to by the cotton industry, that included future targets for sustainable cotton was developed and finalised in 2016; targets have been set for crop yield, farm profitability, water use productivity and efficiency, the carbon footprint, biodiversity and ecosystem services, workforce diversity and capability, the work environment and the prosperity of rural communities. • For example, scientific longitudinal data sets of sustainability metrics were produced that reflect changes in industry practice such as water use efficiency. • The current targets are available as an Appendix in the final report for the project and are to be revised every five years. The current targets are organised by the triple bottom line and include targets for 2019, 2024 and 2029; the next report is therefore due in 2019. • The outputs of the project were disseminated via media releases, the CRDC Spotlight Magazine, cotton and agronomy conferences, and The Cotton Grower Magazine. • Dr Roth presented a paper entitled "Measuring Sustainability in Australian Cotton Farming Systems" at the 6th World Cotton Conference in Brazil in 2016. • The 2014 report recommended that a formal stakeholder reference group be established; the reference group was established and met in June 2016 (Guy Roth, pers. comm., June 2017).
Outcomes	• The sustainability report was published in accord with the international Global Reporting Initiative standards and the Expert Panel on Social, Environmental and Economic Performance of Cotton Production of the International Cotton Advisory Committee; the use of this reporting framework was a world first. • Also, this project provided the first sustainability reporting initiative that included consultation with stakeholders as prescribed by the International frameworks such as the Global Reporting Initiative standards. • There is an increasing acceptance of a continual sustainability improvement philosophy by the Australian cotton industry as exemplified by Cotton Australia's media and policy statements and various initiatives such as a re-invigorated commitment to the myBMP program and the Better Cotton Initiative. • The setting of sustainability targets has been taken seriously by the industry, as exemplified by both Cotton Australia (CA) and CRDC actively participating in the process, and requiring specific changes on drafts (Guy Roth, pers. comm., June 2017).

	• Both CRDC and CA are producing new strategic plans that are likely to include more SMART targets in them (Guy Roth, pers. comm., June 2017). The targets are also consistent with the United Nations 2030 Agenda for Sustainable Development. • A strengthened framework was developed for the industry to discuss the economic, environmental and social issues and relationships within the cotton industry. • Previous fragmented data (social, economic and environmental information) were integrated into a structured framework of data sets; this was a major accomplishment of the project and has provided significantly greater continuity for industry data on a range of issues. • Increased awareness and knowledge of sustainability issues was delivered across the cotton industry as well as for external stakeholders. • Potentially, the project and report resulted in an improved image of the Australian Cotton industry (including its high quality) among cotton communities, the supply chain, and consumers/wider public. • The project played a significant role in a major change in industry leadership attitudes towards sustainability issues and their management. • The report also provided much of the baseline information for the BCI partnership. The BCI is a global sustainability program focused at farm level improvements. Its membership is throughout the cotton supply chain and requires a commitment to sustainable cotton production standards including social and environmental issues like pesticide management and child labour. • CA signed a formal partnership agreement with BCI on behalf of Australia's cotton industry in June 2014. CA will continue to manage the industry's relationship with BCI; a requirement for growers to participate in the Program is that they have to become myBMP certified. • By enhancing the credentials of the sustainability of the Australian cotton industry, the project has made a significant contribution to the image of the Australian cotton industry in the eyes of both the Australian and international communities; for example, see the following recent links: o http://www.abc.net.au/news/2017-06-10/australian-cotton-in-demand-as-consumers-seek-sustainable-fibres/8604774 o http://www.abc.net.au/news/2017-06-10/cottons-credentials:-selling-the-environmental/8609956 o http://www.abc.net.au/news/rural/2014-07-18/cotton-gains/5606434 o http://www.abc.net.au/news/rural/2014-07-18/cotton-gains/5606434
Impacts	• Strengthened the position of the Australian cotton industry as the global leader in sustainable cotton production. • Strengthened the position of the Australian cotton industry's social licence to operate. • Increased support for demand for, and the quality price premium held by, Australian cotton.

Table 7: Logical Framework for Project CRDC 1502

CRDC 1502: Resilience Assessment of the Australian Cotton Industry at Multiple Sites July 2014 to December 2016	
Project Details	Research Organisation: Bel Tempo Period: July 2014 to December 2016 Principal Investigator: Francesca Andreoni
Background and Rationale	There is significant uncertainty about the future environment in which the cotton industry will operate as influenced by such factors as environmental and other

	government policies, input regulation including availability and cost, disease threats, climate change and variability, and cotton prices and profitability and how all these factors may interact. These uncertainties and complexity are recognised as a significant challenge to individual cotton growers, cotton growing regions and the cotton industry as a whole. Industry preparedness through identifying strategies and activities that may be used to manage such uncertainties is therefore important and It was recognised that resilience thinking was an approach that may be able to contribute to better managing these complexities faced by the industry. The investment was undertaken to explore the approach and its potential contribution to cotton industry management.
Objectives	The overall aim of the project was to assess the resilience of the Australian cotton industry and identify where the industry might prioritise efforts to better manage at farm, regional and industry levels to attain the industry's long-term term strategic goals. Specific objectives were: 1. To complete a desktop review of resilience. 2. To develop and refine conceptual models and undertake a resilience assessment of the Australian cotton industry. 3. To deliver resilience assessment and related communications products. 4. To promote and disseminate results and outcomes of the products.
Activities and Outputs	• An assessment of the existing knowledge base about the cotton industry was carried out by undertaking a continuing literature review throughout the project. • A review of key systems and relationships between social, economic and environmental factors associated with the industry was undertaken. • A Reference Group was established and played a supportive and guiding function throughout the project. • A survey of attendees at the Australian Cotton Conference in August 2014 reported that the key on-farm issues for the future included water, climate variability, availability of skilled labour, input and commodity costs and R&D. • Potential shock types or trigger points identified in the survey were global supply and demand, cotton price, the yield of new strains, and Murray Darling Basin rainfall. • Attendees considered it important to address these issues with the ability and willingness to innovate, and with access to markets and financial robustness. • Strengths of the industry reported in the survey included communication and information sharing, an innovative and adaptive culture, industry organisation and cohesion and general management and business ability. • An article was produced for the Spotlight magazine about the project and the results of the survey at the Conference. • Conceptual models and assessments of critical assets, trends and change drivers were developed and acted as inputs to the following workshops. • Three resilience assessment workshops at the farm/region scale were held at Emerald, Narrabri and Griffith in June 2015 with participation of 24 industry stakeholders across the three workshops. • The conceptual models were improved as a result of the workshops. • Some research was undertaken to review available quantitative data related to issues raised by growers and service providers at the workshops. • An industry scale workshop with 17 participants was held in Brisbane in November 2015. • Resilience at farm, region and industry level was distilled as a result of the four workshops resulting in a draft resilience assessment report.

	• A case study was prepared on two cotton growing regions with regard to growers' response to past drought periods (2000-2012); these responses demonstrated the resilience of cotton growers to fluctuations of cotton areas planted and the diversity of responses to water shortages. • Known thresholds or tipping points determining the viability and sustainability of the industry at different scales were identified and an assessment was made of the capacity to manage the industry to avoid these critical thresholds and tipping points. • Key strategies and critical gaps were identified so highlighting key vulnerabilities to long-term viability of the cotton farm/industry. • At the farm scale, the critical thresholds identified were for important farm viability issues including water quality and quantity, soil health, farm profitability and habitat proximity. Thresholds for network connectivity and function, infrastructure investment, native vegetation cover, water quantity and land availability were identified at the regional scale. At the whole-of-industry scale, the critical thresholds identified were for social licence, network connectivity and function and R&D investment. • These thresholds are identified and described in the resilience assessment report and in short video form (for farm scale in particular). The report and two short animated videos are available on the CRDC website at http://www.crdc.com.au/publications/resilience-assessment-australian-cotton-industry. • An assessment of the existing cotton industry sustainability indicators was undertaken and, while some of these can provide insights into resilience, some do not account for vulnerability if already close to a critical threshold. • The review of sustainability indicators was completed and incorporated into the final resilience assessment report; it was suggested that some of the existing sustainability indicators can be used as resilience indicators. • Potential resilience indicators were developed for the Australian cotton industry based on critical thresholds identified; resilience indicators based on general resilience attributes also were developed. • The project concluded that addressing national R&D, regional water availability and infrastructure, farm profitability and farm water availability thresholds should be the highest priority for intervention. • Results were presented at the 2016 Australia Cotton Conference. • Other findings include that the Australian cotton industry has high levels of resilience due to: - cotton being an annual crop, - crops being grown in a wide geographic and climatic domain, - products being associated with low levels of processing, - industry support of effective R&D, - industry exhibiting good network knowledge sharing and rapid adoption of new technologies, and - cotton providing a good return on investment. • On the other hand, the industry faces changing global market dynamics, climate change, narrow genetics, and has to manage various social licence issues such as water and energy use, genetic modification, chemical use, chemical resistance, and biodiversity management. • The resilience assessment report was completed following final consultations and feedback from the Reference Group. • Communication products included an animated video, presentations to a NRM R&D Workshop, the 2016 Australian Cotton Conference, a Regional NRM Biennial Conference, and the Australian Cotton Industry Committee.

	• Communication products for farm scale applications were developed and delivered to the industry. • Recommendations were made to CRDC regarding R&D, capacity building and sustainability indicators.
Outcomes	• The project has increased awareness by cotton growers and the cotton industry of the need for preparedness for managing both expected and unexpected changes, as well as the need to manage distance from key thresholds or tipping points. • The resilience assessment of the cotton industry has identified future challenges and risks to long term profitability and sustainability for the industry. This information should be useful in both future industry level and farm level planning with further implications for setting R&D priorities and different capacity building initiatives. • A range of suggestions for follow-up activities were detailed in the final report (page 10); these included a regular review of the existing resilience assessment and further resilience workshops at farm and industry scale. • As the project has only just been completed, no further workshops or activities are currently planned (Francesca Andreoni and Jane Trindall, pers. comm., June 2017). • There have been some enquiries from industry (e.g. Cotton Info Network) about various aspects of the resilience approach and how it applies to emerging circumstances; responses to these enquiries have been made (Francesca Andreoni, pers. comm., June 2017). • The resilience assessment has increased the capacity of industry leaders to work towards achieving the industry's Vision including via the review and re-development of organisational strategic plans, for example the CRDC 2018-23 Strategic Plan (Jane Trindall, pers. comm., June 2017). • No increases in RD&E resources been allocated to priority areas identified in the resilience report at this time, but such increases may occur under the new CRDC strategic plan, currently under development (Jane Trindall, pers. comm., June 2017). • The cotton industry sustainability indicators have not changed to date as a result of the resilience project, as the indicators are currently still under review (Jane Trindall, pers. comm., June 2017). • The resilience indicators as proposed have so far not been adopted by the cotton industry or CRDC, but this may occur under the new Strategic Plan and revision of the sustainability indicators.
Impacts	• Confirmation of future threats and risks to the cotton industry at grower, regional community and industry levels. • Potential for increased preparedness for, and improved responses to, future impacts on the cotton industry. • Potential for improved allocation of RD&E resources to priority areas identified in the resilience report.

4. Cluster Investment

The Investment

The following tables show the annual investment by project for both CRDC (Table 8) and for researchers and any other investors (Table 9). Table 10 provides the total investment by year from both sources.

Table 8: Investment by CRDC for Years Ending June 2012 to June 2017

Project ID	2012	2013	2014	2015	2016	2017	Total
UNE 1201	117,275	187,328	230,843	1,166,566	0	0	702,012
CFOC 1303	0	61,410	0	0	0	0	61,410
GU 1401	0	0	93,923	93,923	93,923	0	281,769
UNSW 1401	0	0	245,451	224,162	0	0	469,613
RRR 1403	0	0	57,354	57,354	41,702	15,656	172,066
CRDC 1502	0	0	0	204,736	197,331	39,275	441,342
Totals	**117,275**	**248,738**	**627,571**	**746,741**	**332,956**	**54,931**	**2,128,212**

Table 9: Investment by Researchers and Others for Years Ending June 2012 to June 2017

Project ID	2012	2013	2014	2015	2016	2017	Total
UNE 1201	16,595	51,775	53,846	32,667	0	0	154,883
CFOC 1303	0	37,200	0	0	0	0	37,200
GU 1401	0	0	84,000	67,000	70,000	0	221,000
UNSW 1401	0	0	550,940	287,567	0	0	838,507
RRR 1403	0	0	0	0	0	0	0
CRDC 1502[1]	0	0	0	400,000	200,000	0	600,000
Totals	**16,595**	**88,975**	**688,786**	**787,234**	**270,000**	**0**	**1,851,590**

[1] North West Local Land Services made a significant in-kind contribution through the provision of an extensive library of spatial data, reports and assessments on the natural resources and socio-economics of the Namoi and Gwydir regions, as well as staff time to provide access to the information, and assistance with networking and collaboration.

Table 10: Total Investment in the Cluster of Six Projects

Year ending June	CRDC	Researchers and Others	Total
2012	117,275	16,595	133,870
2013	248,738	88,975	337,713
2014	627,571	688,786	1,316,357
2015	746,741	787,234	1,533,975
2016	332,956	270,000	602,956
2017	54,931	0	54,931
Total	**2,128,212**	**1,851,590**	**3,979,802**

Program Management and Extension Costs

For CRDC investment, the cost of managing the CRDC funding was added to the CRDC contribution via a management cost multiplier (1.1325); this was estimated based on the average reported share of 'employee benefits' & 'supplier' expenses in total CRDC expenditure for 2014/15 and 2015/16 (CRDC, 2016). No additional costs of extension were included as most projects were either largely extension-focussed or already included an extension component.

5. Impacts

Seven potential impacts for the sustainability project cluster were assembled from the logical frameworks developed for the individual projects. Some projects delivered multiple impacts. Table 11 summarises the key potential impacts identified and signifies whether a contribution was made to each potential impact by each of the six projects.

Table 11: Contribution by Project to Principal Sustainability Cluster Impacts

Project Code	Increased carbon sequestration by cotton farms	Improved biodiversity and ecosystem management	Enhanced market returns and market positioning for Australian cotton	Reduced operating costs and/or increased profits (e.g. feral pig damage)	Increased scientific research capacity	Contribution to maintenance of social licence to grow cotton	Enhanced community amenities and regional community income spill-overs
UNE1201	✓	✓	✓	✓	✓	✓	✓
CFOC1303	✓	✓		✓	✓	✓	✓
GU1401	✓	✓			✓	✓	✓
UNSW1401	✓	✓		✓	✓		
RRR1403			✓			✓	✓
CRDC1502		✓		✓		✓	

From Table 11, the potential impacts then were condensed and described in a triple bottom line context. Table 12 provides a summary of the principal types of impacts divided into economic, environmental and social categories.

Table 12: Triple Bottom Line Categories of Principal Impacts from the Sustainability Cluster Investment

Economic	• Increased profits from decreased feral pig damage • Contribution to improved market returns and market positioning of Australian cotton
Environmental	• Increased carbon sequestration by vegetation on cotton farms • Increased biodiversity and improved ecosystem management
Social	• Reduced risk of losing part of the cotton industry's social licence to operate • Increased scientific research capacity • Increased regional community well-being through improved amenity values, and from the spill-over effects to the community of increased farm productivity and profitability

Public versus Private Benefits
Many of the benefits identified in this evaluation are cotton industry related and therefore are considered private benefits. Also, two environmental benefits and several indirect social benefits have been delivered including increased spillovers to local communities.

Distribution of Impacts along the Supply Chain
Most impacts (economic, environmental and social) are concentrated at the cotton farm or regional cotton community level. Some of the financial benefits and costs at the farm level will likely be passed along the input and output supply chains in proportion to the elasticities of supply and demand at different stages along the chain.

Impacts on other Industries
Some project outputs (e.g. control of pests) are not necessarily specific to cotton and could be beneficial to other crop industries in cotton areas or on cotton producing farms.

Impacts Overseas
Overseas benefits are not expected to be significant, as most research outputs apply to Australian cotton production environments.

Match with National Priorities
The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 13. The cluster contributes primarily to Rural RD&E Priorities 2, 3 and 4, and to Science and Research Priorities 1 and 2.

Table 13: Australian Government Research Priorities

Australian Government	
Rural RD&E Priorities (est. 2015)	**Science and Research Priorities (est. 2015)**
1. Advanced technology 2. Biosecurity 3. Soil, water and managing natural resources 4. Adoption of R&D	1. Food 2. Soil and Water 3. Transport 4. Cybersecurity 5. Energy and Resources 6. Manufacturing 7. Environmental Change 8. Health

Sources: DAWR (2015) and OCS (2015)

6. Valuation of Impacts

Impacts Valued
Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions, particularly when a high degree of uncertainty was involved. Sensitivity analyses were undertaken for those variables where there was greatest uncertainty or for those that were identified as key drivers of the investment criteria.

Five of the impacts identified in Table 12 were valued. All six projects in the population were identified as contributing to one or more of the five impacts valued in the analysis. The five impacts valued included:

- Maintenance of social licence to continue to produce cotton
- Increased carbon sequestration and greenhouse gas reduction
- A reduction in feral pig economic damage
- Enhanced market returns and market positioning for Australian cotton
- Land and water stewardship enhancing biodiversity and ecosystem integrity

Impacts Not Valued
Not all impacts identified in Table 12 could be valued in the assessment. This applied in particular to two of the social impacts identified. The social impacts identified but not valued included:

- Increased scientific and research capacity
- Increased community well-being through the spill-over effects of increased farm productivity and profitability

Reasons for choosing not to value these impacts included time and resources available, the availability of accurate baseline data and the uncertain relationships between the research outputs, outcomes and impacts.

Valuation of Benefit 1: Maintenance of Social Licence
The right to farm (a social licence) has become contentious, not only in Australia, but elsewhere around the world. This applies to both plants and animals. In the case of cotton, the main issues that have been raised by environmental groups have been related to genetic modification, the use of water resources, and the use of chemicals.

At least four of the six projects in this cluster have been assessed as contributing to this impact (see Table 11). The assumptions used to value this impact have been derived from a series of assumptions related to:

- A conservative estimate of the area of cotton that may be affected
- The value of the lost area of cotton
- The reduced risk of a loss of social licence due to the cluster investment
- The relative contributions of the sustainability cluster investment and the myBMP cluster investment that has been evaluated in a parallel impact assessment.

Specific details of the assumptions for the estimated benefit are provided in Table 14.

Valuation of Benefit 2: Increased Carbon Sequestration
Some improvement in native vegetation management has taken place that has increased carbon sequestration. It is unimportant here as to whether the landowner was rewarded financially or not through mechanisms such as carbon offsets, although this factor affects the beneficiary of the impact. The value of the impact to society is estimated by assuming a value for carbon, the increase in the area of protected vegetation likely to have been driven

by the cluster, and the carbon sequestered per ha of the vegetation protected. A very modest increase in the new area of carbon absorbing vegetation has been attributed to the project cluster in accord with information provided in the project logical frameworks. This benefit does not cover any avoidance of vegetation clearance (maintenance of the existing carbon pump) so is considered conservative.

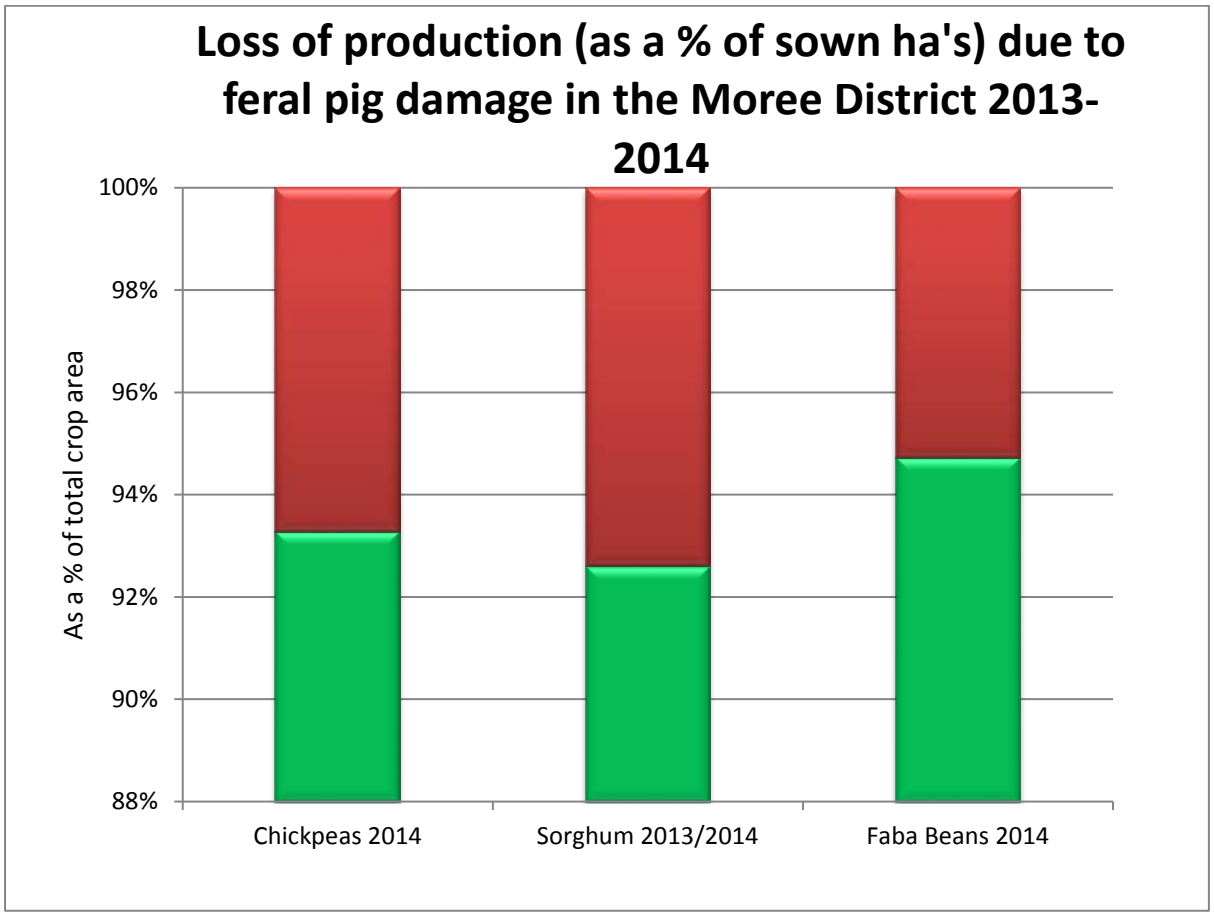
Specific assumptions for the valuation are provided in Table 14.

Valuation of Benefit 3: Reduction in Pest Damage

Feral pigs impact cotton producers in terms of damaging cotton crops and the environment by spreading disease, causing soil erosion, destabilising waterways and damaging wildlife.

An indication of the crop damage imposed on Moree cropping farms in 2013-14 is provided in Figure 1. Note that the red area signifies the percentage loss e.g. for chickpea the loss was between 6% and 7% (of 100% sown, 6-7% was lost).

Figure 1: Loss of Production due to Feral Pig Damage in the Moree District 2013-2014



Source: Lou Gall, pers. comm., June 2017

The destruction of 1,500 pigs as was reported from Project CFOC 1303, would have only short-term impacts as feral pig populations breed and multiply quickly. There are no recognised or published damage functions for pigs for specific crops such as cotton. Hence, an estimate of pig damage has been made based on the value of a cotton crop per ha, and the area of cotton that may have been positively impacted by removing approximately 1,500 pigs. An allowance for helicopter and shooting costs has been included. The impact on other

grain crops has not been included so any estimates made on the damage avoided by the shooting are conservative.

Specific assumptions are made in Table 14. Also, the period of benefits has been reduced after the first year and gradually declines to zero in 2018.

Valuation of Benefit 4: Enhanced Market Returns and Market Positioning

Consumers are increasing their interest in the environmental and social sustainability of cotton production. In 2014, Cotton Australia signed a landmark agreement with the BCI. The BCI is a global sustainability program focused at farm level. Australian cotton growers with myBMP certification can be granted a licence to join the BCI and enjoy a price premium for their cotton; a conservative estimate of $3 per bale has been used in the valuation as the likely premium (Nicole Scott, pers. comm., 2017).

Specific assumptions for valuing this benefit are provided in Table 14.

Valuation of Benefit 5: Enhanced Land and Water Stewardship Enhancing Biodiversity and Ecosystem Integrity

At least four of the six projects contributed to this impact as indicated in Table 6. There is a considerable area under native vegetation on cotton farms. Part of this vegetation, particularly that pertaining to areas around rivers and creeks, is ecologically valuable and some of this area has been already protected by reduced stocking rates and fencing management.

The four projects combined are assumed to have motivated or influenced 20 cotton growers to take action to further protect biodiversity and vegetation ecosystems in part of their native vegetation area.

Ascertaining an appropriate value per ha of the ecosystems protected is a difficult task. The approach taken in this evaluation is to rely on the average value of competitive grants made via the Commonwealth's Environment Stewardship Program between 2007 and 2011. This represented a surrogate for the government's willingness to pay landholders to protect ecosystems on their properties. The area involved was over 56,000 ha for which payments totalling of $52.3 million were made, resulting in an average grant of $180 per ha.

Specific assumptions for valuing this impact are provided in Table 14. It should be noted that the $180 per ha also covers the cost to the landowner of protecting the vegetation as well as landowner direct benefits such as from savings in insecticides caused by improvements in biodiversity.

Counterfactual

There was no generalised counterfactual used in the analysis. Instead, individual counterfactuals were used for two benefits valued as provided in the with and without scenarios in Table 9 (Benefits 1 and 3). For Benefits 2, 4 and 5 the benefit valued referred only to the additional number of farms or areas assumed to be influenced by the Sustainability Cluster investment.

Summary of Assumptions

A summary of the specific assumptions made for valuation of the impacts is shown in Table 14.

Table 14: Summary of Assumptions

Variable	***Assumption***	***Source***
Benefit 1: Avoided Loss of Social Licence to Produce Cotton		
Assumed annual average cotton area	380,000 ha	5-year average area harvested 2012 to 2016), ABARES (2016)
Margin of irrigated cotton over irrigated wheat (assumed next best crop)	$1,500 per ha	Derived from Cotton and Wheat Gross Margin Analysis, Cotton Seed Distributors, March 2008
Maximum proportion of industry assumed lost to cotton	20%	Agtrans Research
Probability of loss occurring without project cluster	10%	
Probability of loss occurring with project cluster	8%	
Year loss first avoided due to cluster	2019	
Number of years to reach maximum loss	5	Agtrans Research
Attribution of this benefit to the Sustainability cluster versus the total benefit attributed to the myBMP and Sustainability clusters combined	25%	
Benefit 2: Increased Carbon Sequestration		
Value of carbon sequestration to the environment	$11.82 per tonne (CO2 equivalent)	Based on Average Price per tonne of abatement for Auction 5 for Emissions Reduction Fund (Clean Energy Regulator 2017)
Tonnes sequestered	100 tonnes per ha	Based on total site carbon for River Red Gum vegetation averaging 216 tonnes per ha (project UNE 1201)
Total area of new vegetation managed	40 ha	Agtrans Research
First year of management change	2015	
Linear ramp up period to 100 tonnes	10 years	
Benefit 3: Reduction in Pest Damage and Control Costs		
Feral Pig Damage		
Number of pigs destroyed by project activity	1,500	Final Report for Project CFOC 1303
Gross margin of cotton crop	$2,917 per ha	NSW DPI (2014/15)
Area of damage	250 ha	Agtrans Research
Gross margin reduction across damage area without shooting	50% of gross margin per ha	
Maximum gross margin reduction with shooting of 1500 pigs	10% of gross margin per ha	
Years of maximum benefits	2013 and 2014	

Last year of some benefits	2017	
Ramp down of impacts	75% 2015, 50% 2016, 25% 2017	Agtrans Research
Cost of helicopter and shooting	$10,000 over two years (2012 and 2013)	Based on Research Report CFOC 1303
Benefit 4: Enhanced Market Returns		
Additional number of growers assumed to be involved with Best Cotton Initiative due to the Sustainability Cluster investment	5, over the period 2014 to 2018	Agtrans Research estimate
Total average annual cotton output	3.49 million bales (average past five years)	Cotton Australia (2017e)
Number of cotton farms	1,200	Cotton Australia (2017c)
Average number of bales per farm	2,907	3.488 million/1200
Increase in price due to BCI certification	$3 per bale	Cotton Australia (2017d) and Nicole Scott, pers. comm., 2017
Average annual revenue gain per farm	$8,721	2,907 bales x $3 per bale
Benefit 5: Improved Biodiversity and Ecosystem Protection		
Assumed annual average cotton area	380,000 ha	5-year average area harvested 2012 to 2016, ABARES (2016)
Cotton area as % cotton farm area	14%	Cotton Australia (2017b)
Area of cotton farms	2,714,286 ha	100/14 x 380,000 ha
Area of native vegetation as % total cotton farm area	42%	Cotton Australia (2017a)
Area of native vegetation	1,140,000 ha	2,714,286 x 100/42
Number of cotton farms	1,200	Cotton Australia (2017c)
Area of native vegetation per farm	950 ha	1,140,000/1200
Number of new growers improving management as a result of sustainability cluster investment	5	Agtrans Research
Area of native vegetation protected per farm changing management	25%	Agtrans Research
Total area protected	1,118 ha	950 x 5 x 25%
Value of grants made to landholders via the Commonwealth ‘s Environmental Stewardship Program 2007-2011 (surrogate for community’s willingness to pay)	$180 per ha (estimated by dividing $152.3 million by 56,527 ha across NSW, QLD and SA)	Burns et al (2016)
Period agreed under conservation management plan within the above program	15 years	Burns et al (2016)
First year of benefits	2016	Agtrans Research
Last year of benefits	2030	Agtrans Research

7. Results

All past costs and benefits were expressed in 2016/17 dollar terms using the Implicit Price Deflator for GDP (ABS, 2016). All benefits after 2016/17 were expressed in 2016/17 dollar terms. All costs and benefits were discounted to 2016/17 using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the Modified Internal Rate of Return (MIRR). The base analysis used the best available estimates for each variable, notwithstanding a level of uncertainty for many of the estimates. All analyses ran for the length of the investment period plus 30 years from the last year of investment (2016/17) to the final year of benefits assumed.

Investment Criteria

Tables 15 and 16 show the investment criteria estimated for different periods of benefits for both the total investment and for the CRDC investment respectively. The present value of benefits (PVB) attributable to CRDC investment only, shown in Table 16, has been estimated by multiplying the total PVB ($12.26 million) by the CRDC proportion of real investment (56.2%).

Table 15: Investment Criteria for Total Investment in the Six Projects
(Discount rate 5%, Re-investment rate 5%)

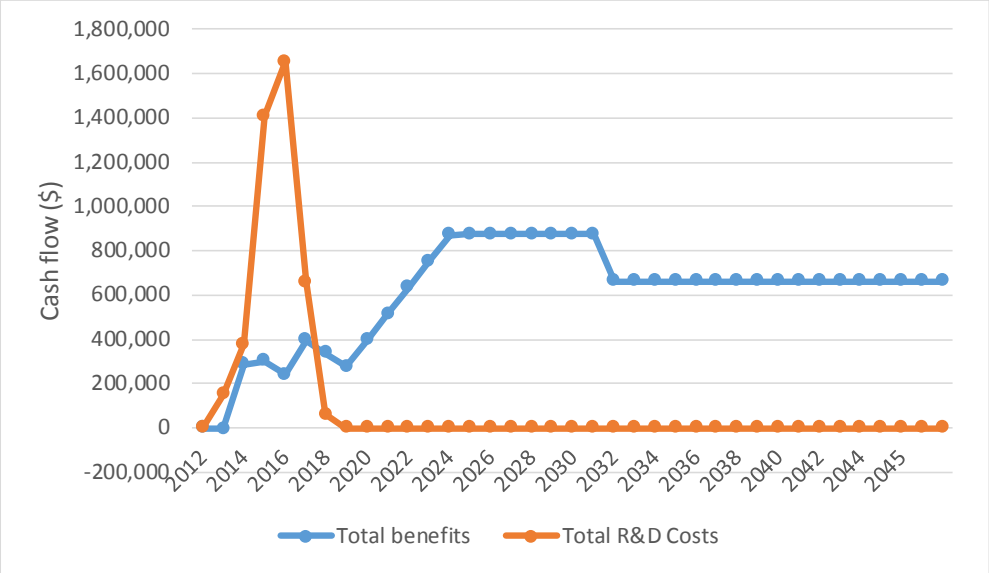
Investment criteria	Number of years from year of last investment						
	0	5	10	15	20	25	30
Present Value of Benefits ($m)	1.71	3.88	6.84	8.96	10.33	11.41	12.26
Present Value of Costs ($m)	4.85	4.85	4.85	4.85	4.85	4.85	4.85
Net Present Value ($m)	-3.15	-0.97	1.99	4.10	5.48	6.56	7.40
Benefit-Cost Ratio	0.35	0.80	1.41	1.85	2.13	2.35	2.53
Internal Rate of Return (IRR) (%)	negative	negative	11.2	14.0	14.9	15.2	15.4
Modified IRR (%)	negative	negative	9.9	10.7	10.1	9.6	9.1

Table 16: Investment Criteria for CRDC Investment in the Six Projects
(Discount rate 5%, Reinvestment rate 5%)

Investment criteria	Number of years from year of last investment						
	0	5	10	15	20	25	30
Present Value of Benefits ($m)	0.96	2.18	3.84	5.03	5.80	6.41	6.88
Present Value of Costs ($m)	2.73	2.73	2.73	2.73	2.73	2.73	2.73
Net Present Value ($m)	-1.78	-0.56	1.11	2.30	3.07	3.67	4.15
Benefit-Cost Ratio	0.35	0.80	1.41	1.84	2.12	2.34	2.52
Internal Rate of Return (IRR) (%)	negative	negative	11.0	13.8	14.7	15.1	15.2
Modified IRR (%)	negative	negative	9.9	10.7	10.2	9.6	9.1

The annual undiscounted benefit and cost cash flows for the total investment for the duration of investment period plus 30 years from the last year of investment are shown in Figure 2.

Figure 2: Annual Cash Flow of Undiscounted Total Benefits and Total R&D Costs in the Project Cluster



Sources of Benefits

Given the assumptions made, the contribution of each of the individual benefits to the Total PVB are shown in Table 17.

Table 17: Contribution of Each of the Five Benefits to the PVB

Source of Sustainability Benefit	Contribution to PVB ($m)	Share of Benefits (%)
Benefit 1: Social Licence	7.23	59.0%
Benefit 2: Carbon	0.67	5.5%
Benefit 3: Feral Pigs	1.15	9.4%
Benefit 4: Market Returns	0.76	6.2%
Benefit 5: Ecosystem Protection	2.45	20.0%
Total PVB	12.26	100.0%

Sensitivity Analyses

A sensitivity analysis was carried out on the discount rate. The analysis was performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values. Table 18 presents the results. The results showed a moderate sensitivity to the discount rate.

Table 18: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	5% (base)	10%
Present value of benefits ($m)	22.35	12.26	8.17
Present value of costs ($m)	4.31	4.85	5.45
Net present value ($m)	18.04	7.40	2.71
Benefit-cost ratio	5.19	2.53	1.50

An additional sensitivity analysis was conducted on one other variable. The largest contributor to the Total PVB was the risk avoidance benefit for the social licence to farm

cotton. Investment criteria for various scenarios for the reduction in risk are provided in Table 19.

Table 19: Sensitivity to Change in Probability of Loss of Social Licence
(Total investment, 30 years, 5% discount rate)

Investment Criteria	Reduced Probability of Loss Occurring with Cluster Investment		
	10% reduced to 5%	Base: 10% reduced to 8%	10% reduced to 9%
Present value of benefits ($m)	23.11	12.26	8.64
Present value of costs ($m)	4.85	4.85	4.85
Net present value ($m)	18.25	7.40	3.79
Benefit-cost ratio	4.76	2.53	1.78

Confidence Ratings

The results produced are highly dependent on the assumptions made, many of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table 20). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made

Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 20: Confidence in Analysis of Cluster

Coverage of Benefits	Confidence in Assumptions
Medium-High	Medium-Low

Coverage of benefits was assessed as medium-high as a range of benefits were identified and valued. While some impacts were not valued, these were subjectively assessed as being minor relative to those valued.

Confidence in assumptions was rated as medium to low as many of the assumptions had to made with limited data on the use of the various knowledge outputs of the projects. On the other hand, the assumptions that have been made for valuing the benefits from these investments are potentially conservative. Again, the principal reason for this was a lack of evidence available regarding current adoption by the cotton industry of practice changes that may have been driven by the investments, as well as the average and range of the value to growers for making such changes. In this regard, it is suggested that CRDC further develops its capacity to monitor, report and/or assess impacts and adoption from individual or grouped project investments. This can be aided via such mechanisms as assembling feedback from growers at industry events, consultant and agronomist surveys, and specific case studies that could be included in final project reports.

8. Conclusions

The six projects grouped into the Sustainability Cluster were all successfully completed and all produced knowledge relevant to both productivity and natural resource management issues at both cotton farm and industry levels. Impacts were identified that addressed both farm productivity and environmental improvement.

Funding for the six projects in the cluster totalled $4.85 million (present value terms) and produced aggregate total expected benefits of $12.26 million (present value terms). This gave a net present value of $7.4 million, a benefit-cost ratio of 2.5 to 1, an internal rate of return of 15.4% and a modified internal rate of return of 9.1%.

References

ABARES (2016) Australian Commodity Statistics, Canberra

Australian Bureau of Statistics (2016). 5204.0 - Australian System of National Accounts, 2015-16. Canberra: Australian Bureau of Statistics. Accessed June 2017 at: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5204.02015-16?OpenDocument

Burns E, Zammit C, Attwood S and Lindenmayer D (2016) The Environmental Stewardship Program: Lessons on creating long-term agri-environment schemes in "Learning from agri-environment schemes in Australia: Investing in biodiversity and other ecosystem services on farms" edited by Dean Ansell, Fiona Gibson and David Salt, published 2016 by ANU Press, The Australian National University, Canberra, Australia. Accessed May 2017 at: The Environmental Stewardship Program: Lessons on creating long-term agri-environment schemes (PDF, 433KB)

Clean Energy Regulator (2017) Accessed June 2017 at: http://www.cleanenergyregulator.gov.au/ERF/Auctions-results/april-2017

Cotton Australia, (2017a) Accessed May 2017 at http://cottonaustralia.com.au/australian-cotton/environment

Cotton Australia (2017b) Accessed May 2017 at http://cottonaustralia.com.au/uploads/publications/2015_Cotton_Annual_-_Statistics_Booklet.pdf

Cotton Australia (2017c) Accessed June 2017 at http://cottonaustralia.com.au/cotton-library/fact-sheets/cotton-fact-file-the-australian-cotton-industry

Cotton Australia (2017d) Accessed June 2017 at http://cottonaustralia.com.au/cotton-to-market/better-cotton-initiative

Cotton Australia (2017e) http://cottonaustralia.com.au/cotton-library/statistics

CRDC 2016, *CRDC Annual Report 2015-16,* Cotton Research and Development Corporation, Narrabri, NSW

CRDC & Cotton Australia 2014, *Australian Grown Cotton Sustainability Report,* Guy Roth – Roth Rural and Regional Pty Ltd, Narrabri

CRRDC 2014, *Impact Assessment Guidelines – Version 1, May 2014*, CRRDC, Canberra

DAWR 2015, *Rural Research and Development Priorities*, Department of Agriculture and Water Resources, Canberra, ACT, accessed January 2016, http://www.agriculture.gov.au/ag-farm-food/innovation/priorities

Charlotte P. Iverach, Dioni I. Cendón, Stuart I. Hankin, David Lowry, Rebecca E. Fisher, James L. France, Euan G. Nisbet, Andy Baker & Bryce F. J. Kelly, (2015) *Assessing Connectivity Between an Overlying Aquifer and a Coal Seam Gas Resource Using Methane Isotopes, Dissolved Organic Carbon and Tritium,* Scientific Reports 5, Article number: 15996 https://www.nature.com/articles/srep15996

NSW DPI Cotton Gross Margins Cotton Gross Margins, Furrow Irrigated Cotton, Central & Northern NSW ~ 2014-2015, Accessed May 2017 at:

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/577902/cotton-gross-margins-2014-2015-central-and-northern-nsw.pdf

OCS 2016, *Science and Research Priorities,* Office of the Chief Scientist, Department of Industry, Innovation and Science, Canberra, accessed 02 Nov 16, http://science.gov.au/scienceGov/ScienceAndResearchPriorities/Pages/default.aspx

Roth G (2010) Economic, Environmental and Social Sustainability Indicators of the Australian Cotton Industry, Accessed May 2017 at http://www.crdc.com.au/sites/default/files/pdf/Economic%2C%20social%20and%20environmental%20indicators%20report.pdf