Australian Cotton: Accounting for value chain sustainability and competitive advantage

Second Year Report: Objective 3

Strategy and Competitive Advantage

A Strategic Management System

January 2015

This second year report has been submitted to the Cotton Research and Development Corporation (CRDC) as part of the project: Australian Cotton: Accounting for value chain sustainability and competitive advantage (CRDC reference code: UTS1201). The project is jointly funded with UTS Business School.

Please note, feedback from the CRDC and other key stakeholders will be incorporated into an updated version if the report is subject to general release.

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Executive Summary

This report provides analysis of the strategic processes currently followed by key stakeholders in the Australian cotton industry. Our findings suggest that in order for Australian Cotton to maintain a competitive advantage, there needs to be: a clearer understanding of the existence and leveraging of an 'open strategy' process; a change of focus in the relationship between competitive and operational strategy; modifications to the way strategies are diffused and implemented across the industry. This report also situates the four other reports that form the Year Three deliverables of the *Australian Cotton: Accounting for Value Chain Sustainability and Competitive Advantage* project.

Two key problems exist in the development and implementation of strategy at an industry level. First is the lack of 'decision rights' over the development and implementation of strategy as often these are done by different organisations. Second is that the industry strategy needs to have 'fit' within the broader competitive and economic environment. An example of misfit is seen in the focus on leveraging sustainability credentials for market premiums within current supply chain structures; whereas sustainably credentials deliver value in more realistic ways such as maintaining the 'social licence to operate' and improved resource allocation opportunities. All of this exists in a broader context of an industry facing significant threats including: drought; competition from China; slowing productivity growth and unfavourable terms of trade.

We undertook an extensive analysis of the workings of the Australian cotton industry conducting 91 interviews, reviewing archival documents dating back to 1974 and undertaking extensive observational data collection and analysis.

We have developed an overarching architecture for strategy processes for the Australian cotton industry which draws upon the current and historical success in being able to identify strategic threats and mobilise R&D for appropriate responses. We extend this by developing an 'open strategy' approach which gives a way for the cotton industry to move forward in a collaborative but directed manner. We have also identified a number of challenges which are addressed in the related reports.

Summary of key recommendations:

- Develop a more systematic approach to managing anticipatory systems which identify the triggers for required strategic responses
- Develop a clearer link between the industry's competitive strategy and individual growers' operational strategy during strategy formation and evaluation
- Enable the emergence of a cohesive competitive strategy through the 'managed' implementation of operational strategy

- Maintain efficient and appropriate contracting of R&D to underpin ongoing development of operational strategies
- Consider adopting a ‘more nuanced’ approach to diffusion mechanisms to enable the industry wide implementation of operational strategy
- Better inform development of supply chain strategy with reference to the underlying market structures
- Better inform operational decision making with improvements to environmental and economic trade-offs to enable an effective collective response to threats such as water and energy use

List of Abbreviations Used

BMP	Best Management Practice
CA	Cotton Australia
CRC	Cotton Cooperative Research Centre (Cotton CRC)
CRDC	Cotton Research & Development Corporation
EMA	Environmental Management Accounting
MCS	Management Control Systems
M&E	Monitoring and Evaluation
NCEA	National Centre for Engineering in Agriculture
NUE	Nitrogen Use Efficiency
R&D	Research & Development
RD&E	Research, Development & Extension
SR	Strategic Response
STEEP	Socio-cultural, Technical, Ecological, Economic, Political (potential strategic threats)
UTS	University of Technology Sydney

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1. Introduction

1.1 Report Objective, Milestone and Performance Indicator

This report forms the deliverable for:

Performance Indicator 3.2: Prototype strategic management system that enables strategic opportunities to emerge from within the cotton industry.

This sits as the final aspect of the following objective and milestone.

Objective 3: To develop a method in which my BMP and improvements in its sustainability information content can be leveraged to develop improved competitive strategy in international cotton markets.

Milestone 3.2: Establish how information on sustainability and related issues can be leveraged for competitive advantage for the Australian cotton industry

The strategic uncertainties and risks facing the cotton industry have been substantial over an extended period of time and industry responses have been admirable and on the whole relatively successful. However, as the industry moves forward there is a need to maintain the kind of vigilance and proactiveness that has been evidenced to date. A key focus of many industry stakeholders has been on strategic content, with less attention on strategic process.

Our project and this report has a focus on identifying what effective strategic processes currently exist in the Australian cotton industry; where challenges exist in strategy processes; and how the industry moves forward.

Two key problems exist in the development and implementation of strategy - particularly when dealing with a more collective strategy process at an industry-level. First is the lack of decision rights[1] over the development and implementation of strategy. The cotton industry has managed to overcome some of these issues with the current strategy creation process, but still faces structural problems with strategy implementation processes. Our project will identify how these problems can be overcome, and provide guidance on how to develop and implement both competitive and operational strategy.

A second problem the industry faces – in particular with the focus on leveraging sustainability for development of competitive strategy – is that the strategy of the firm (or in this case an industry)

[1] This is the extent to which an individual or group is empowered to make a decision. The right to make the decision needs to be matched with the accountability for that decision.

needs to have some ‘fit’ within the broader competitive and economic environment. Given that cotton is for the most part sold into commodity markets which at this point do not reward grower sustainability as ‘genuine’ business value proposition, the capacity for the Australian cotton industry to garner environmental credentials and to have this priced in a differentiation strategy is highly problematic. This issue will be addressed briefly in this report and dealt with in more detail in the report: *Value chain architecture for sustainable competitive advantage*. This in not to say that sustainability has no current value, rather that the value created from investing in sustainability can stem from sources such as: maintaining ‘social licence to operate’; improved resource allocation opportunities; lower input costs through more efficient operations; reduced operating risk.

1.2 Report Structure

This report outlines the components of a strategic management system that we have designed for the Australian cotton industry. This contains three key components.

First in Section 2 we outline the three components of the overall strategic system an input (antecedent factor or trigger), an action (a strategic response) and an output (a strategic outcome). We explain how the components of this operate and the key processes that the Australian cotton industry already has in place. We also identify the issues and processes that the industry needs to focus on moving forward. Some of the issues that require more detail will be outlined in this report and then expanded upon in other related reports – all of which form part of the overall CRDC/UTS project - *Australian Cotton: Accounting for value chain sustainability and competitive advantage.*

Second in Section 3 we explain the open strategy process in reference to the strategic system and how this operates in the Australian cotton context.

Third, in Section 4 we address a number of other strategic considerations within the Australian cotton industry, such as supply chain sustainability and operational decision making.

1.3 Theses Contributing to this Report

The report also draws from, and contains insights from the following doctoral theses under completion as part of the project:

- Thambar, P., 2015, The Role of Management Control Systems in Open Strategy Processes
- Sutton, N., 2014, Managing cooperation control problems in inter-organisational research and development exchanges
- Pham, H., (yet to be completed), Design of Environmental Performance Measurement Systems for Agriculture
- Jing, K., (yet to be completed), Why sustainability doesn't pay; Analysis of underlying market structures in the Australian cotton supply chain

The report also draws from, and contains insights from the following honours theses completed as part of the project:

- Lowe, P., 2012, Factors That Affect the Adoption of Management Accounting Systems in an Australian Agricultural Setting
- Soco, S., 2014, The Role of Management Accounting for the Control of Energy in an Agricultural Setting
- Saroufin, K., 2014,Risk Management: Interdependency and Operational Risk

All these theses will be made available to CRDC.

2. Strategic management systems

Strategic management systems typically comprise of three components an input (trigger) and action (a strategic response) and an output (a strategic outcome).

Figure 2.1: High Level Strategic Management System Components

Section 2.1 will outline the antecedent processes to identify triggers; Section 2.2 will consider strategic responses; and finally Section 2.3 will consider strategic outcomes and their implications.

2.1 Antecedent process

These are the processes that enable evaluation of whether a Socio-cultural, Technical, Ecological, Economic or Political (STEEP) factor requires a strategic response. If so then the STEEP factor becomes a 'trigger'. Beyond the day to day monitoring of information cues, the ability to interpret STEEP factors and determine whether a strategic response is needed requires strategic insight. This will be explained in more detail in Section 3.2.3.

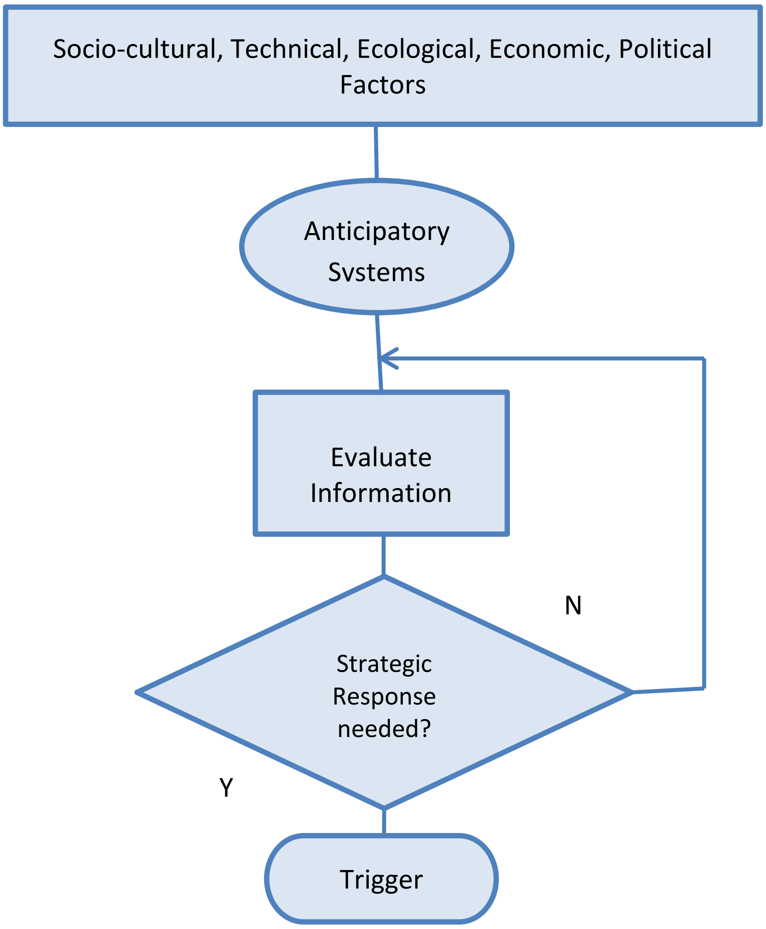

Figure 2.2: Antecedent (Trigger) Process

2.1.1 Triggers

Factors in the external environment can become a trigger to the strategic process. These are commonly categorised as STEEP (Socio-cultural, Technical, Ecological, Economic, Political) factors.

Factor	Examples	Strategic Impacts
Socio-cultural	People resources, population demographics, income levels and distribution, skills and education, social mobility of labour, lifestyle changes, attitudes to work and leisure and consumerism	Influence the types of customers and their buying behaviour, the type of employees and their aspirations and capabilities
Technological	Rates of new technology adoption, new inventions, rates of obsolescence of current technologies, research and development investment and competencies, and social-media systems and platforms	Impact how the firm develops its operational activities and strategy. New technologies facilitate the design of improved processes, products and services which have the ability to reduce costs and increase yields and profit margins
Ecological	Air and water pollution, toxic emissions, chemical spills and industrial accidents, as well as non-replenishable resources such as animal and plant species, water and land, soil-based minerals	Threaten firms' 'social licence to operate' and impose higher economic costs through their impact on access to resources, socio-cultural factors such as attitudes of customers and staff, and production efficiency and costs.
Economic	National and regional gross domestic product (GDP), terms of trade, exchange rates, general interest rates, input resource access and costs, levels of unemployment, disposable income levels and inflation rates	Affect the availability and impact of other industry-level factors such as socio-cultural factors, higher input resource costs, production efficiencies and costs at the firmlevel
Political	Taxation policy, government funding for R&D and innovation, competition policy, laws relating to employment, occupational health and safety and product safety	Establishes regulation that specifies how operational activities are designed and implemented, provides a basis for legitimate business activity for a firm which influences how strategy is developed and implemented

Table 2.1: Examples of Strategic Impact of STEEP Factors

STEEP factors often require strategic responses because they have tangible financial consequences for individual firms (Carpenter & Sanders 2009; Chesbrough 2003, 2006 & 2007; Johnson et al 2005), by altering costs of production and the potential for market share, market growth and revenues. In addition, STEEP factors influence the decisions of growers as to whether they remain in the cotton industry, as commercial, social or climatic considerations determine whether it is worthwhile for enterprises to continue cotton production.

For the purposes of this report these external economic and structural factors are not deemed to be responsive to internal strategic policy settings. They are discussed further in the *Value chain architecture for sustainable competitive advantage* report.

2.1.2 Anticipatory systems

Anticipatory systems exist when firms capture, structure and generate information in one instant to predict events at a future instant (Rosen, 1985). Anticipatory systems can be used to observe STEEP factors and to generate signals and information that prompt strategically insightful, pro-active actions to be taken in the present to minimise future impacts. In this role the anticipatory systems form an important component of the Antecedent Process in evaluating if a strategic response is required and potentially generating a trigger for further action.[2]

Anticipatory systems may manifest as manual measurement systems, digital information and monitoring systems, or social-based networks, action groups and committees. They may operate at different levels; for example they include the monitoring conducted by individual growers as well as the broader systems oriented around certain catchment areas, states or the entire industry. Relevant examples in the cotton industry include surveys of diseases, pests and weeds, resistance monitoring, rainfall and climate modelling, cotton market reports and financial indices, surveys of cotton grower practices and data collected about the average cost, revenue and profitability of cotton farms.

Typically anticipatory systems are developed on an ad-hoc basis as a way of monitoring a particular external factor. They vary in the frequency in which information is collected and evaluated and the degree to which information is made available to other stakeholders. One reason for this is that continuous observation is only rendered effective if the anticipatory systems used are of high quality, signalling information that is relevant for evaluation. Nonetheless, there remain substantial opportunities to develop a more integrated, structured approach towards the development, maintenance and use of anticipatory systems within the Australian cotton industry, with at least three key benefits:

- broader stakeholder access to all relevant information
- closer ongoing monitoring of relevant STEEP factors
- greater leverage from existing anticipatory systems (i.e. through integration of separate systems)

[2] Anticipatory systems are also used in Strategic Outcome Process (see Section 2.3).

2.2 Strategic response process

Where a strategic response is required, an assessment then needs to be undertaken to determine if an opportunity or a threat is being presented and whether innovation should be initiated as the solution. The outcome of this Strategic Response Process is then evaluated in the Strategic Outcome Process discussed in Section 2.3.

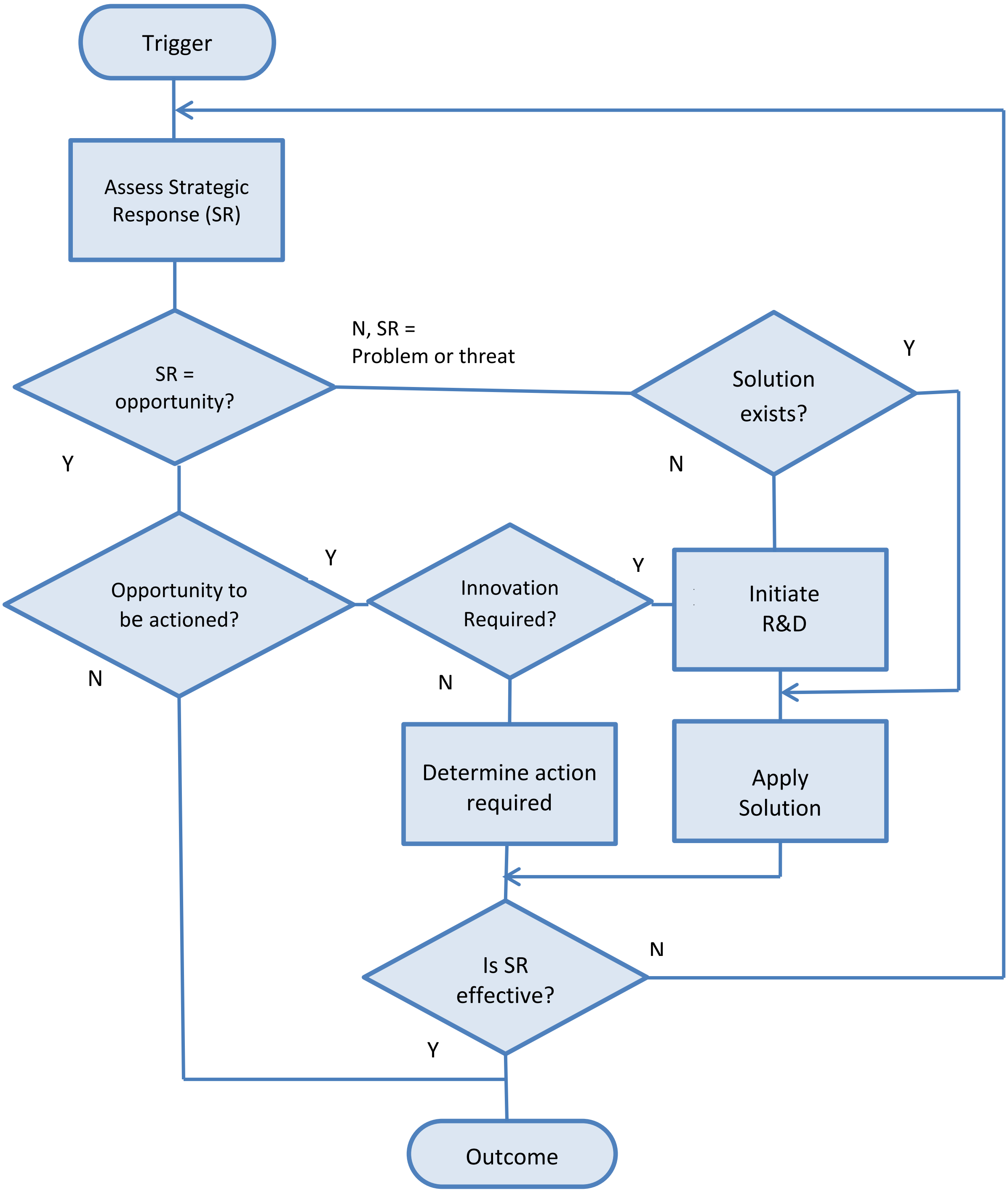

Figure 2.3: Strategic Response Process

2.2.1 Strategic management of the R&D process

In our depiction of the strategy process in Figure 2.3, when no current solution exists for problems, threats or opportunities, R&D needs to be initiated[3]. The initiation of R&D has been a key strength of the Australian cotton industry over a considerable period of time.

Maintaining this core capability as an industry will be central to the sustaining of competitive advantage going forward. The R&D contracting process enables;

- Addressing the threats and opportunities that have *similar impacts* on a number of firms in the industry; and
- Addressing the problems that individual firms do not have the strategic assets to mobilise to manage the impacts of the external factors.

When initiating R&D, the contractual relationship between funders and providers of research becomes extremely important. Transaction Cost Economics helps lay out what makes contracting of research particularly challenging. We labelled these 'cooperation problems'. These arise due to the three characteristics of the underlying transaction.

- **uncertainty**: the likelihood that unanticipated disturbances or changes will occur
- **asset specificity**: the degree to which providers are required to invest in specialised assets that cannot be redeployed to alternative uses without loss of value or significant cost
- **frequency:** the degree of recurrence of a funder's transactional activity

Significantly these characteristics are not only common, but often desirable attributes of R&D project exchanges.

These underlying characteristics give rise to three types of cooperation problems in the context of Australian cotton. These are:

(i) the risk of costly setup and negotiation of projects (ex ante);
(ii) the risk of poor project investment decisions (at the point of contract); and
(iii) the difficulty in evaluating and enforcing contract compliance (ex post).

Currently these are addressed largely through existing management strategies embedded within the CRDC. However going forward, the future viability of R&D contracting in Australian cotton will have to address a number of latent challenges which may become more salient. This is addressed in more detail in the report to the CRDC; *Ensuring cooperation in R&D contracting*.

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[3] Some of the ideas in this section are drawn from the report to the CRDC *Ensuring cooperation in R&D contracting*, authored by Nicole Sutton, David Brown and Dianne Hiles.

2.3 Strategic outcome process

When the strategic response and outcome required by the trigger have been determined, their impact on the framework of all existing strategic considerations needs to be assessed. If these are manageable, the outcome can be rolled out to the relevant user community. Feedback collection is important for reviewing the implementation process and future monitoring.

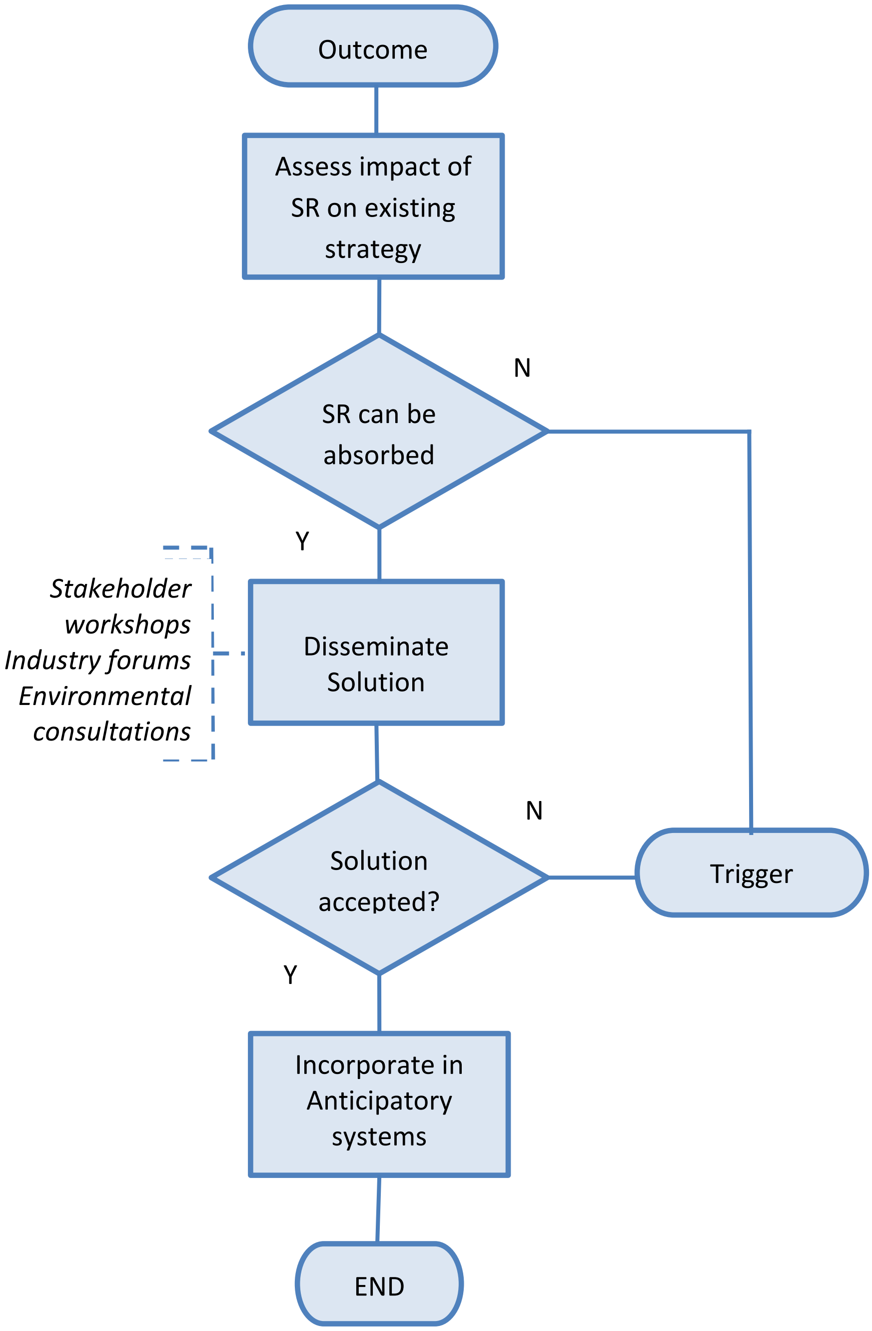

Figure 1.4: Strategic Outcome Process

2.3.1 Disseminating the solution

As outlined earlier in this report, key challenges for implementing the outcomes of R&D on an industry-wide basis are;

- It is difficult to implement strategy, objectives or other initiatives the way this is done within autonomous business units through the use of management control systems (MCS).
- Industry leaders do not have decisions rights over choices made within individual organisations. Even the introduction of regulation provides real challenges in trying to influence decisions made within firms.

It would seem that the way to address strategy and organised responses to challenges and threats is through a well-developed innovation diffusion process[4]. However, enabling the diffusion of innovation and extension of R&D can be challenging. To provide insight into these challenges we conducted two case studies of instances where the diffusion of innovation has been problematic:

- Environmental management related best practices, risk evaluation and assurance mechanisms in myBMP, rolled out as an online accreditation package in 2010
- Specific energy efficiency management practices embedded within myBMP that relate to nitrogen application and the use of diesel

The barriers and factors affecting operational adoption have been explored in our research, with these key findings:

- There is a widely-held perceived conflict between the investment in time and resources required and the potential benefits
- Concerns about the compatibility in design to grower needs and the broader connectedness between growers and myBMP stakeholders
- Communication issues around what was targeted to growers and the availability and timeliness of system support
- Growers prioritised the activities that contributed to the improvement of yield, while energy efficiency activities were found to be of relatively less importance. Nitrogen optimisation is prioritised over cost efficiencies.

[4] The detail of this is contained in the report for the CRDC *Diffusion of best practices in the Australian Cotton Industry* authored by David Brown, Paul Brown, Nicole Sutton and Dianne Hiles.

Being able to successfully diffuse innovation through a broader population opens up another significant opportunity for the Australian cotton industry. As a top down specification of strategy is highly problematic – given the problems outlined above – a more considered approach would be to;

- Have a clear understanding of the desired competitive strategy.
- Have a clear understanding of the practices that need to exist in the operational strategy to deliver this competitive strategy.
- Diffuse these operational practices through the population which will enable the competitive strategy to emerge within the industry.

This should facilitate implementation of a more cohesive competitive strategy despite not being able to employ traditional mechanisms such as MCS.

3. Open strategy processes

The prior section outlines the three basic processes embedded within strategic management systems. In the context of the Australian cotton industry these systems and processes occur outside the bounds of individual firms, and thus rely on open strategy processes to develop collaborative Strategic Responses (SR) to triggers identified within the industry by key stakeholders.

3.1 Open strategy

Open strategy is defined as a *strategy process with strategic activities that take place beyond the firm boundary and at the inter-firm level*[5].

These strategic activities include the establishment of overarching strategic objectives, experimenting with new ideas, the carrying on of strategic dialogue between managers from different firms to develop new strategic information and the development of collaboration mechanisms to carry out the open strategy process.

R&D and innovation have been identified as the key elements of the strategy process where strategic activities have been carried beyond the firm boundary. This has involved sharing of strategic assets to develop new ideas and information that can be brought back into the firm to improve firm-level operational and competitive strategy processes. For example, Proctor and Gamble, a global corporation providing consumer goods, sources more than fifty per cent of their new product ideas from outside the organisation, from firms and individuals who are willing to engage in open R&D and innovation (Huston and Sakkab 2006).[6]

These open strategy process activities form the core of the Strategic Response denoted in Figure 2.3, and focus on sharing and pooling strategic assets to carry out R&D and innovation, to commercialise the outcomes from these activities, to develop new information that can be used to improve organisation-level operational activities. These improved operational activities can be used to implement competitive strategic objectives and positioning that help the organisation to manage the challenging external factors.

3.2 What is required for open strategy to work?

First, there needs to be a set of conditions which provide an economic incentive for participation (described in Section 3.2.1). Second, there needs to be a set of collaboration mechanisms that operate between organisations (see Section 3.2.2). Third, there needs to be what research has defined as

[5] Further information about the nature of strategy is provided in Appendix 1.
[6] Further examples of open innovation can be found in Chesbrough & Appleyard (2007) and Chesbrough (2003).

‘meta-capabilities’ (see Section 3.2.3). The combination of these three elements is depicted in Figure 3.1.

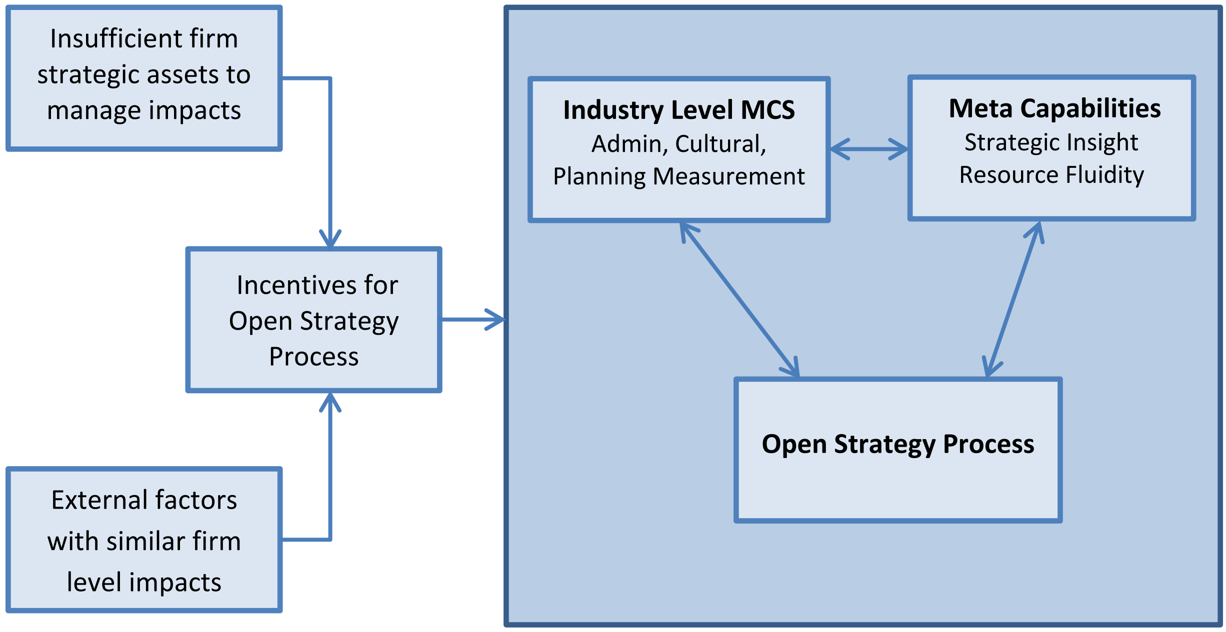

Figure 2.1: Framework of Open Strategy Processes

3.2.1 Incentives for open strategy processes

As discussed in Section 2, environmental factors (STEEP factors) can operate as triggers which are identified by the anticipatory systems as requiring a Strategic Response. Two important conditions have been identified that create the incentives for organisations to respond to these triggers using an Open Strategy Process (see Table 3.1). The first condition is the existence of external factors which have *similar impacts* on a number of organisations in an industry. The second condition is the *limited strategic assets* of an individual organisation which can be used to manage the impacts of external factors that are identified as a trigger requiring a Strategic Response.

When these two conditions exist, an organisation is influenced to explore collaboration opportunities beyond its own boundaries through engaging in open strategy processes to develop strategic information that can be used to develop improved organisation-level strategy.

	Similar Impacts	Limited Strategic Assets
Definition	External factors which have *similar impacts* on a number of organisations (either individually or collectively) an industry. These impacts influence the strategic choices made by the organisation.	Individual organisations don't have sufficient strategic assets which can be used to manage the impacts of the external factors.
Examples	Ecological issues related to cotton pests.	R&D and innovation, commercialisation skills
Consequences	Impact operational activities which are manifest in production costs and revenue yields.	Organisations are influenced to share and pool these strategic assets to enable the creation of new strategic information which can benefit all organisations.

Table 3.1: Characteristics that make a STEEP factor a trigger for an Open Strategy Process

3.2.2 Collaboration mechanisms

Collaboration mechanisms are industry-level management control systems and include administrative systems (industry organisations and workshops committees and conferences), cultural systems (values, symbols and clans), and planning (strategic plans and operational plans) and measurement systems (environmental audits and annual reports). These mechanisms enable open strategy process activities between organisations and at industry level, providing the collaborative capability to craft Strategic Responses to identified triggers.

Collaboration mechanisms provide the basis for open strategy processes. The context for open strategy refers to establishing the values, culture and the forums that enable and encourage managers from different organisations:

- to engage in strategic dialogues
- to share information and ideas
- to experiment with new ideas through R&D
- to develop new information which can be used in strategy formation and implementation (Flamholtz et al, 1985).

Collaboration mechanisms facilitate:

- the context to establish an open strategy process:
  - value systems which reinforce a collaborative culture
  - an industry forum such as a committee with a specific mandate and agenda
- activities relating to organisational control practices such as:
  - planning,
  - measurement
  - feedback
- feedback practices such as identifying performance variances which help to identify strategic gaps that need new information.

3.2.2.1 Administrative systems

These systems provide a collaborative framework that enables managers from different organisations to carry out an ongoing strategic dialogue which facilitates open strategy processes. There are 3 types of systems: industry organisations, workshops committees and conferences and procedures and policies.

Industry organisations, workshops, conferences and committees

Industry organisations such as CA, the CRDC and the Cotton CRC focus on strategy and policy advocacy, to provide strategic direction for industry R&D, to fund and manage industry R&D programmes, and to develop a collaborative network of research partners to carry out industry R&D projects. These industry organisations have functioned *between* individual firms to establish the context for collaboration in the open strategy process.

	Role	Outcome
Enabling Functional Specialisation	Specialising in key strategic areas such as strategy and policy, R&D direction, R&D funding, and R&D resource and skills provision.	Provides scale and a collective forum for raising strategic issues. Provides distribution of the strategic information developed through the open strategy process, to individual firms within the industry.
Enabling networks and relationships	Industry organisations are able to connect individual firms and managers through shared membership or through other means such as secondments so managers can develop networks and relationships outside their firm boundary.	Provides the basis for managers from different firms to develop their meta-capability relating to strategic insights by enabling strategic dialogue and the sharing of ideas.

Table3.2: Role of Industry Level Organisations

	Role	Outcome
Enabling Formal Lines of Authority & Accountability	Role of a Chairperson and shared agenda	Enables governance and accountability for bringing stakeholders together to discuss strategic issues and finding solutions.
Enabling networks and relationships	Workshops, committees and conferences also connect individual firms and managers and enable expansion of their networks and relationships outside their firm boundary.	Provides the basis for a wide range of industry participants to take part in discussions and decision-making.

Table 3.3: Role of Workshops Committees and Conferences

Policies and procedures

Procedures and policies are a type of administrative management control system which provides a way of governing strategic and operational activities. BMP and myBMP are examples of a procedures and policies system which provides a basis for sharing information with a wide range of stakeholders. This kind of mechanism provides coordination and sharing of new information in a number of ways.

- New information from R&D projects is developed into best management practice procedures. This interaction enabled collaboration, coordination and sharing of new information.
- Individual firms and managers are able to access new information for use in firm-level strategy development and implementation. This information can be translated into best management practices and made available to all organisations through procedures and policies in a systematic manner.
- This mechanism provides a basis for individual organisations to assess their operational strategy and operational activities, to identify gaps for improvement, and to plan for the development and implementation of new strategy.
- Finally, this mechanism provides a basis for assessing and managing operational risks at the organisation-level by enabling organisations to identify and prioritise the gaps between their current strategic and operational activities and these best management practices.

The advantage of BMP (and the intention of myBMP) was that the procedures and policies were developed as a holistic management control system at the industry-level and *between* firms, with the potential to provide a basis for collaboration in the open strategy process. They could also be used to operate as a linking mechanism between the industry-level open strategy process and the firm-level strategy process.

3.2.2.2 Strategic and operational planning

Planning systems and practices (strategic plans, operational plans) provide a basis for coordinating activities in three ways.

- Enable coordination, development and alignment of strategic objectives across the industry.
- Focus attention of managers on actions required and the expected behaviours to meet these objectives and identify action that needs to be taken to improve operational activities. This assessment also provides a basis for R&D projects to develop new information on improved cotton growing practices.
- Provides a basis for coordinated actions. The formal strategic objectives and the measurement of current operational activities of cotton growers provide a basis for managers from different organisations to plan and implement actions required to improve these activities.

3.2.2.3 Measurement – environmental audits and annual reports

Measurement systems and practices such as environmental audits provide a basis for assessment of current performance, identification of variances and their causal factors, and feedback and discussion which enable managers to identify strategic options and actions for performance improvements.

3.2.2.4 Collaboration enabled by between organisation management systems

The open strategy is developed through coordinated discussions, decisions and actions between managers and firms who collaborate through the platform provided by industry organisations (such as CA and the CRDC), industry mechanisms such as workshops, committees and conferences, and planning systems (strategic and operational planning) which establish strategic direction in a number of key areas (such as R&D). Similarly, measurement systems (environmental audits and annual reports) are used as industry-level and *between* firm management systems to assess performance and to identify key variances and options which provide strategic information for the open strategy process. Collectively, all of these industry-level management systems enable the delivery of an open strategy process.

3.2.2.5 Culture

Culture can be both a form of control as well as the context in which control is exercised.

- Culture is often defined as 'the way we do things around here'. It is generally formed through the values of the individuals and groups who work in and across organisations.
- Values are the broad preferences for appropriate action or outcomes. They reflect a person's sense of right and wrong.

Culture can be quite influenced by the way relationships are structured (i.e. who 'hangs out with' whom). The values set by early cotton growers and other industry participants (such as scientists) helped to establish the context for open strategy processes by developing a culture of collaboration which has provided direction and purpose and influenced behaviour. This was also facilitated by a number of other mechanisms.

- Co-location of growers and researchers in some areas enabled managers from different organisations to communicate more freely and share ideas and values.
- Industry-level organisations and other administrative arrangements (conferences, committees and workshops) provided a platform for this common culture to be shared and extended more broadly.

It would seem that all of this has had some influence on forming the cotton industry 'clan'. Open strategy processes benefit when managers from different organisations have compatible social values and beliefs in order to enable cooperation and collaboration.[7]

3.2.3 Meta-capabilities

Meta-capabilities are broad organisational attributes that enable the operational pursuits which are required by firms and managers to carry out open strategy process activities. Two meta-capabilities have been identified in the management literature (Doz & Kosonen, 2010). The first meta-capability is strategic insight. The second meta-capability is resource fluidity.

3.2.3.1 Strategic insight

Strategic insight is managers' ability to assess strategic issues in the industry environment and their impact on the firm's strategy. Insight often comes from seeing these strategic issues in non-traditional ways. Through combining foresight on current strategic issues with insight into how these strategic issues impact on the firm's strategy in the present and in the future, managers are able to engage in open strategy processes to develop new information that facilitates improved development and implementation of strategy.

Strategic insight is developed by carrying out three key activities:

- **Challenging strategic objectives** provides a signal to managers that fresh strategic thinking and information is required to develop actions to meet these objectives.
- **Experimenting with new ideas** to develop options to position the firm better to achieve strategic objectives. A significant way to carry out this experimenting is by undertaking R&D projects.
- **Maintenance of a strategic dialogue** between managers from different organisations. The strategic dialogue between different groups of managers provides a basis for new ideas to arise and to be investigated which can lead to new information to improve strategy.

Strategic insight is developed and deployed with the help of collaboration mechanisms. Industry-level management control systems (industry organisations and planning and measurement systems).

3.2.3.2 Resource fluidity

Resource fluidity is the capability to deploy capital, intellectual and human resources. It has been identified in the management and strategy literature as a useful meta-capability for improved strategy

[7] An alternative mechanism for enabling collaboration is the provision of economic incentives.

processes (Doz & Kosonen, 2010). Industry-level collaboration mechanisms have enabled resource fluidity to support open strategy processes:

- Industry organisations provided the basis for capital allocation mechanisms to be deployed in an efficient and targeted way towards R&D projects. These projects provided research outcomes which were developed into new strategic information and practice.
- Industry organisations, workshops and conferences were also used to enable the modular deployment of people to open strategy process activities. This brings people with specific research skills together to share ideas and work on R&D projects. The industry organisation for R&D capability provision has provided a platform to bring people resources from different R&D partners together and for them to be co-located in the same region.
- The inclusion of key managers in workshops and conferences enabled sharing of information and execution of a range of actions to develop new information for operational strategy development. The inclusion of key managers enabled the modular deployment of people resources who continued to maintain their functional roles within individual firms.

4. Other strategic considerations

4.1 Supply chain strategy

A key issue to be addressed by the Australian cotton industry is how to deal with current supply chain structures in the context of their competitive strategy and the necessity to have a continued focus on environmental sustainability and recognition in revenues for R&D innovation. Earlier work in our project indicates that the current cotton market structure and supply chain arrangements are posing considerable challenges for growers to leverage price premiums by signalling their on-farm sustainability performance to downstream markets. A comprehensive analysis of these challenges is presented in the report to CRDC *Value Chain Architecture for Sustainable Competitive Advantage*.

Key findings and recommendations are;

- Various cotton eco-labelling schemes, now including myBMP, have been commanding some premiums in the downstream markets, but the premiums exhibit a declining trend over time
- Economic analysis and stakeholder interviews both indicate that cotton growers with superior sustainability performance are unlikely to be rewarded by the current market structure
- The tension between myBMP's ineffectiveness to generate premiums and the pressure to continuously invest into sustainability is of paradoxical nature that requires specific resolution
- A comprehensive supply chain framework is developed which examines the strategic fitness among value chain constituents as well as relevant external factors for competitive advantage
- Target Costing is a strategic cost management and supply chain coordination tool, which is recommended for facilitating better stakeholder alignment and coordination when the Australian cotton industry undergoes its transitional period towards sustainable competition

4.2 Decision making at an operational level

A key challenge faced by cotton growers is to operate in a more sustainable way, particularly in maximising water and energy efficiency. In the report to CRDC, *Australian Cotton: Accounting for value chain sustainability and competitive advantage*', we provide the industry with the architecture for an integrated management system which provides the link between crop management decisions at the farm level and the overall water and economic sustainability performance of a farm.

Our overall model includes the synthesis of three models; furrow irrigation model (SIRMOD), crop production model (APSIM) and our developed economic model. The aim is to enable cotton growers to make more economically and environmentally sustainable decisions. To that end, we provide some practical examples of how to apply our work, including a demonstration of how changes in current furrow irrigation systems can help cotton growers to improve water and economic sustainability performance (i.e., decreasing irrigation water applied to a crop while increasing crop yield and crop profitability for a crop business).

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Appendix 1 Strategy

Strategy is a plan to achieve strategic objectives which needs to be resourced (Johnson et al, 2005). Traditionally, a firm acquires strategic assets and uses these assets to carry out operational activities that secure the firm a competitive advantage and builds firm performance (Carpenter & Sanders, 2009). Such strategic assets relate to capital and people and usually remain within the firm (Chesbrough, 2003).

Types of strategy

There are three distinct types of strategy

- Corporate strategy establishes the broad direction for the organisation.
- Competitive strategy determines the strategic positioning.
- Operational strategy determines the operational activities that are needed in the value chain to help achieve the competitive strategy.

Senior managers form the strategy and all other managers are involved in strategy implementation only (Ansoff, 1965, Porter, 1991).

Competitive strategy

Porter (1991, 1985 &1980) argued that a firm develops a competitive strategy that helps to build competitive advantage leading to firm performance *but* implements this through a well-designed operational strategy. The open R&D and innovation process and related activities provide the basis for new information which a firm is able to bring back inside the firm to develop and fine tune its operational strategy to enable the achievement of its competitive strategy (Porter, 1991, Langfield-Smith, 2007, 1997).

Operational strategy

Operational strategy is based on operational activities which are organised into a value chain (Porter, 1991). These generic operational activities were defined by Porter (1991) to include primary activities such as:

- marketing and sales
- production and operations
- inbound logistics
- support activities such as procurement and research and development (R&D)

For Porter (1991), an operational activity is the "basic unit of competitive advantage" (p102) and the successful achievement of the competitive strategy is determined by how well these operational activities are structured and performed by the firm. In effect, Porter (1991) has argued that the ability to structure and resource these operational activities forms the basis for a distinctive competitive advantage for the firm. Chesbrough (2003) has supported this view, focusing on innovation and R&D activities, and arguing that "internal R&D was a valuable strategic asset, even a formidable barrier to entry by competitors in many markets" (p35).

R&D and innovation activities form part of the firm's value chain of operational activities which consolidate into the firm's operational strategy (Porter, 1991).

Australian Cotton: Accounting for value chain sustainability and competitive advantage

Objective 1: To Establish How Sustainability Information Can Be Leveraged by Farmers to Create More Value from the Cotton Value Chain

Third Year Report: Value Chain Architecture for Sustainable Competitive Advantage

January 2015

This third year report has been submitted to the Cotton Research and Development Corporation (CRDC) as part of the project: Australian Cotton: Accounting for value chain sustainability and competitive advantage (CRDC reference code: UTS1201). The project is jointly funded with UTS Business School.

Please note, feedback from the CRDC and other key stakeholders will be incorporated into an updated version if the report is subject to general release.

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Disclaimer: The report is intended for internal use by CRDC and Cotton Australia only.
Users are reminded of the need to ensure that information upon which they rely is up to date and appropriate. Further, the recommendations in this report are of a general nature, and accordingly the authors encourage readers to seek independent advice prior to making financial decisions.

EXECUTIVE SUMMARY

In this final year report we analyse the current arrangement of Australian cotton value chain and provide feedback on its implications to cotton grower value. Our findings suggest that cotton's sustainability credentials are less likely to be leveraged by the growers to avoid the intensifying competition overseas. Instead, a Target Costing approach is recommended which may be useful for enhancing the structural fit of Australian cotton value chain and paving new ways to compete.

The current cotton market structure is posing three considerable challenges for cotton growers to gain additional value by signalling their myBMP credentials to downstream. First is the lack of 'authentic' demand for cotton sustainability information and buyers' unwillingness to tolerate price premiums associated with cotton's eco-labels. Second is the downstream domination by the retail-NGO driven cotton labelling schemes which are 'non-premium' and becoming increasingly available from lower cost cotton producers. Third are the information asymmetry post-farm-gate and the lack of integration of cotton sustainability information and cotton revenue flows which further reduce growers' chance of getting direct market compensation for on-farm sustainability investments.

We undertook an extensive analysis of the current Australian cotton value chain using economic and organisational analytical models. This is supported by evidence collected from domestic stakeholder interviewees, downstream informants, archival documents and alternative cotton value chains under which premiums were enabled for grower's cotton eco-labels.

We constructed a value chain architecture describing the relevant factors that may potentially enable growers to directly compete with their sustainability credentials. The issue that growers are not able to gain sufficient myBMP related premiums is seen as a misfit of the current value chain components. As an overview to the current report, we found and suggested the following:

Summary of key findings and recommendations:

- Various cotton eco-labels, now including myBMP, have been commanding some premiums in the downstream markets, but most of the premiums have dissipated in recent years
- More confrontational competition reduces buyers' tolerance for higher prices, therefore limits the effectiveness of the differentiation strategy based on the cotton product alone
- The tension between myBMP's ineffectiveness in generating premiums and the pressure to continuously invest in sustainability requires specific resolution by industry decision makers
- Target Costing is a strategic cost management and supply chain coordination tool, which is useful for maintaining the industry competitiveness as it undergoes the transitional period towards sustainable competition

Table of Contents

List of Abbreviations Used

ABCD	Archer Daniels Midland, Bunge, Cargill and Louis Dreyfus
ACVC	Australian Cotton Value Chain
BCI	Better Cotton Initiative
BM	Business Model
BMP	Best Management Practice
CA	Cotton Australia
CmiA	Cotton made in Africa
CRC	Cotton Cooperative Research Centre (Cotton CRC)
CRDC	Cotton Research & Development Corporation
R&D	Research & Development
TC	Target Costing
UTS	University of Technology Sydney

1. Introduction

1.1 Report objective, milestone and performance indicator

This is the final report from our three-year study on how Australian cotton growers can use on-farm sustainability information to obtain more value from the cotton supply chain. This third year report aims to synthesise findings and industry feedback, and to provide some recommendations on how to manage strategically some of the challenges surrounding the production and marketing of myBMP accreditation within a supply chain context, that is when companies need to collaborate with each other sequentially in order to deliver myBMP information to downstream customers. The report addresses the following objective, milestone and performance indicator:

OBJECTIVE 1 (for all 3 years): To establish how sustainability information can be leveraged by farmers to create more value from the cotton value chain.

Year 3 Milestone 1.3: Articulate an underlying market structure and set of factors that both reduce and enable cotton farmers' capacity to gain value from sustainably related activity.

Year 3 Performance Indicator 1.3: Construct a supply chain architecture that has the potential to enable farmers to create value in the supply chain.

1.2 Overview of a three-year evolutionary research endeavour

Figure 1.1 summarises the project's evolutionary path spanning three years from 2011 to 2014.

The project's initial focus was on constructing a supply chain information tool for systematically signalling myBMP related information through the supply chain. This was based on the assumption that there is suitable market structure in place for growers to implement a differentiation market strategy by leveraging myBMP credentials. A benchmarking analysis of myBMP against the more widely accepted BCI program was also conducted in the first year to highlight myBMP's differentiable attributes, based on which some premiums may potentially be generated in the marketplace.

Our collected evidence did not support the above assumptions and it became clear that a closer look and better understanding of the Australian cotton value chain was necessary. Consequently, we shifted our research focus during the second year towards studying the value chain factors potentially enabling and/or prohibiting the marketing potential of myBMP. In the current third year report we synthesise previous findings and provide practical recommendations.

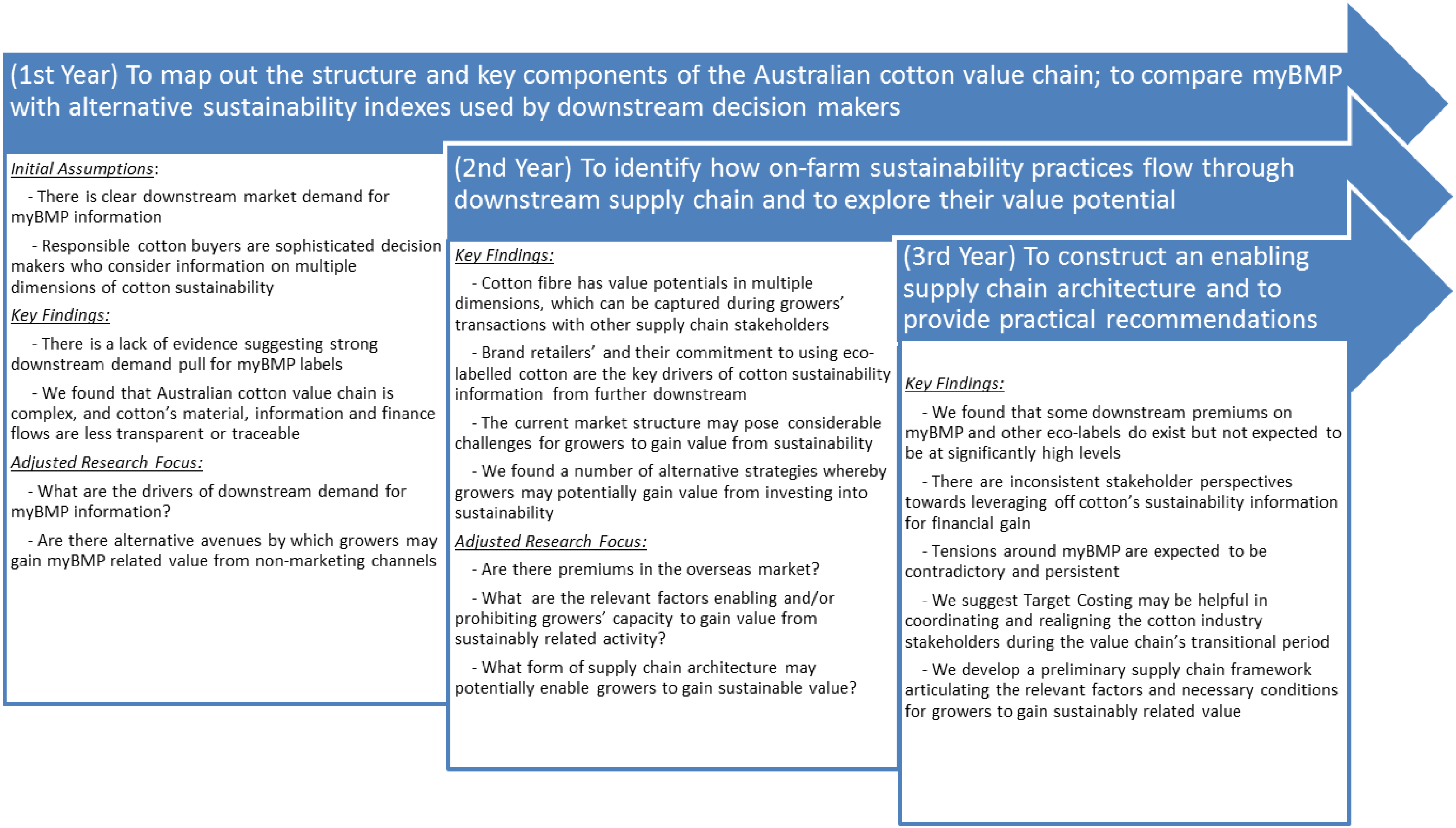

Figure 1.1: An evolutionary research project over a three-year period

1.3 Current report structure

The current report is organised as per the following structure:

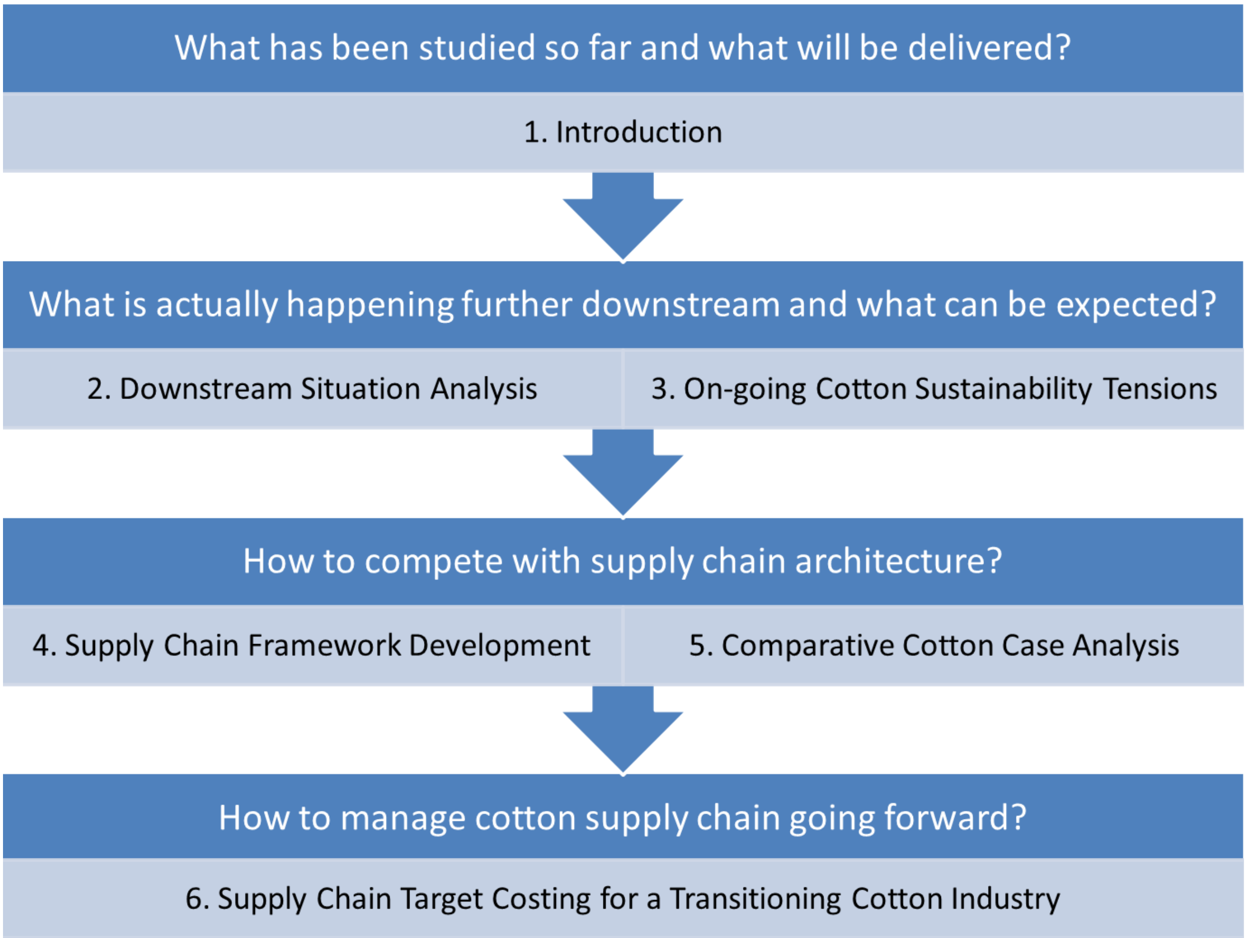

Figure 1.2: Report outline

2. Downstream Situation Analysis

2.1 Do myBMP or other eco-labels command price premiums in the overseas cotton markets?

We have interviewed stakeholders operating in the cotton industry's largest overseas market. The Chinese BCI supply chain stakeholders were chosen because they represent important downstream market segments, have been exposed to a variety of cotton eco-labels, and the Australian grown myBMP cotton is currently sold into these channels as 'BCI' cotton. The interviewed stakeholders include Chinese cotton trading firms, an integrated textile company (farm to finished garment), an Australian grower's office based in Beijing, and the official BCI organisers based in Shanghai, China[1]. The evidence collected is consistent among the interviewees.

The cotton eco-labels have been commanding some premiums in the overseas markets but their levels have been steadily declining over time. Premiums on myBMP are currently quoted at around 2 USc/lb or 10 USD/bale in some downstream overseas markets.

Key findings from the downstream BCI (myBMP) supply chains:

- myBMP is not a recognisable brand, but it is now considered as a substitute for the brand retailer-driven BCI labels
- Some level of premiums have been consistently charged to subscribing organisations under various cotton eco-labelling schemes, regardless of the 'premium free' philosophies widely publicised by the official organisers
- The main driver for the premiums is attributed to the opportunistic dealings by intermediary supply chain actors, and premiums on BCI labels were at one time reaching 30%-40%[2]
- Premiums have followed a declining trend and most are now stabilised within the range of 1 *USc/lb* to 3 *USc/lb*. E.g. 2 *USc/lb* for BCI is explicitly quoted on international cotton markets[3]
- When BCI cotton is locally grown and processed by a fully integrated Chinese cotton company, premium is strictly prohibited at all supply chain touch-points and not charged to the end retailer based in Shanghai (the world's second largest apparel company as of 2014)

[1] Brand retailer perspectives at further downstream are represented by their supply chain counterparts and BCI organisers, which are then checked with their press releases and reports for consistency.
[2] Estimates supplied by BCI China office.
[3] Figures were crosschecked with informants from different Chinese trading houses.

"myBMP is just beginning to be known as BCI… To my knowledge there has never been premium-free BCI cotton since we started trading them."
– A Chinese purchaser experienced in sourcing sustainably labelled cotton products

2.2 Economic analysis – how to explain the observed premiums?

Responsible cotton such as BCI is a new but growing sector in the overseas market. The Chinese stakeholders have verified our second year analysis that mills' purchasing of BCI cotton is a 'pure' brand retailer driven phenomenon initiated by their placement of actual orders specifying the amount of BCI cotton to be used by downstream manufacturers[4].

As the intangible BCI label becomes a new product attribute that is not easily substituted, mills' and their downstream supply chain partners will be, to a certain extent, willing to pay additional costs to secure downstream orders and satisfy client requirements. This willingness to tolerate some premiums gave rise to trading opportunities for firms operating in the international cotton marketplace.

One way to describe the observed downstream market structure is economic competition featuring many growers who sell products that are not perfect substitutes – in this case cotton with or without specified eco-labelling. Appendix A1 contains the economic analysis for understanding and predicting the premium patterns. The main findings are:

Key findings from the economic analysis on the market structure:

- In the short-term, suppliers of responsibly labelled cotton into the downstream market are able to charge a premium on the cotton label resulting in above market profits
- As more equally qualified suppliers enter the market, customers' demand will continuously shift towards being less tolerant towards premiums attached to cotton eco-labels
- From a long-term perspective, premiums attached to cotton sustainability labels are expected to dissipate and are unlikely to revert to historical high levels

Figure 2.1 below is a graphical illustration of a possible cotton sustainability premium pattern, supported by our field evidence collected from downstream value chain stakeholders.

[4] The specified amount various conditioning on the market dynamics at the time of order.

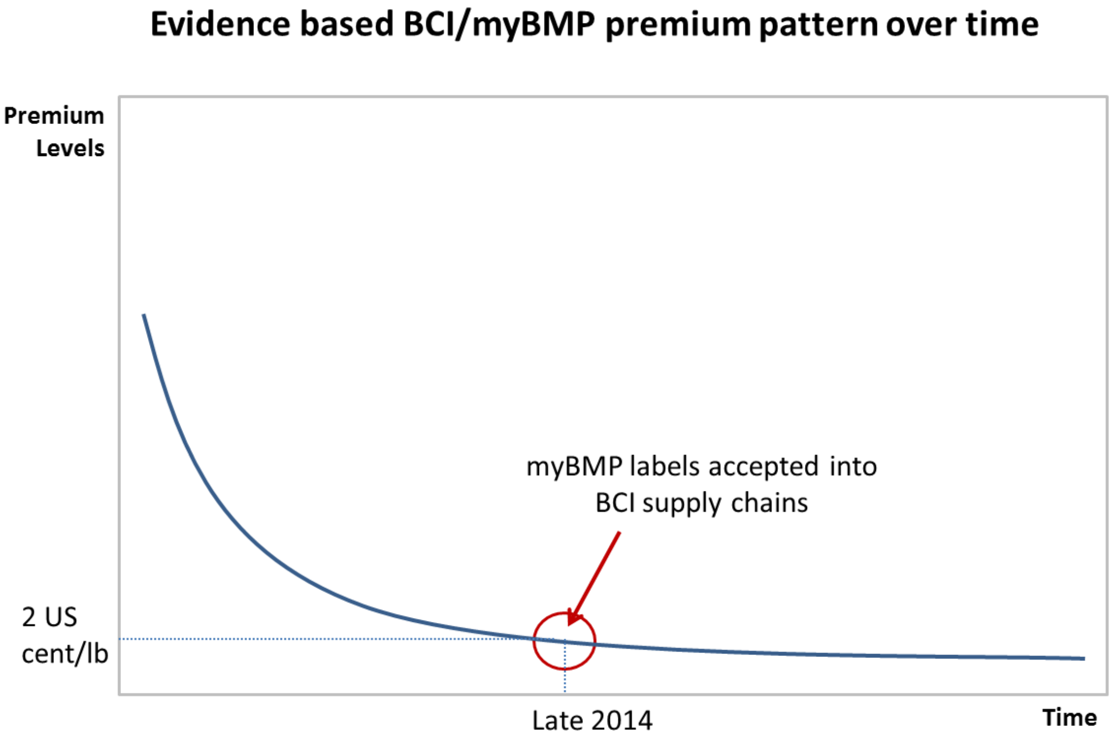

Figure 2.1: Trajectory of cotton eco-label premiums

There may be considerable challenges for implementing a product differentiation strategy aimed at leveraging myBMP related premiums in downstream market.

Next, we present findings on some actual stakeholder perspectives along the cotton value chain. By complementing economic analysis with a more socially oriented angle, we aim to achieve a more realistic outlook of the challenges surrounding cotton sustainability premiums.

2.3 Value chain stakeholder perspectives

2.3.1 Premiums – A compromise between inconsistent downstream perspectives

When asked to provide official comments, the overseas supply chain stakeholders expressed negative sentiment towards the premiums associated with any cotton eco-labels. For example, the premiums on BCI accreditation have been openly criticised by official program organisers and brand retailers as a 'problem', which has been driven by opportunistic dealings of some players who are going against the non-premium nature of BCI scheme[5]. This view is also reinforced during conference discussions involving stakeholders forming other parts of the BCI supply chains in China.

[5] BCI Annual Report, 2013; WWF and IKEA Project Report, 2014.

According to the ‘premium-free’ philosophy officially described under various eco-labelling schemes, sustainable labels such as myBMP are seen as an ***order qualifier*** – the baseline requirement suppliers need to satisfy before they can participate in the downstream bidding process for business orders[6]. For example, buyers can expect similar fibre qualities from many suppliers on the market.

An ***order winner*** on the other hand is what will actually bring business to farm gate. From a commodity buyer’s perspective this is primarily **cost**. More specifically, the growers are seen as taking the responsibility to maintain their costs at sufficiently low levels so that they can profit under cotton eco-labelling schemes, without needing financial compensation from downstream clients.

Table 2.1: Under the officially described responsible cotton supply chain

<table>
<tr><th>Order Qualifier</th><th>Costs Borne By</th><th>Order Winner</th><th>Costs Borne By</th></tr>
<tr><td>Quality</td><td>Suppliers</td><td rowspan="4">Low Price</td><td rowspan="4">Client</td></tr>
<tr><td>Lead Time</td><td>Suppliers</td></tr>
<tr><td>Service Level</td><td>Suppliers</td></tr>
<tr><td>*myBMP Label*</td><td>Suppliers</td></tr>
</table>

However, the actual downstream dynamics may differ. As a newly emerged product attribute, certain cotton’s sustainability credentials make them less easy to be substituted by traditional fibre. As retailers start to specify amount of BCI/myBMP cotton their buying orders, the label can be seen as an order winner for which certain costs have to be borne by retailers so long as there is short supply.

Table 2.2: Under the observed cotton supply chain

<table>
<tr><th>Order Qualifier</th><th>Costs Borne By</th><th>Order Winner</th><th>Costs Borne By</th></tr>
<tr><td>Quality</td><td>Suppliers</td><td rowspan="2">Low Price</td><td rowspan="2">Client</td></tr>
<tr><td>Lead Time</td><td>Suppliers</td></tr>
<tr><td>Service Level</td><td>Suppliers</td><td>*myBMP Label*</td><td>Client</td></tr>
</table>

[6] In a buyer-driven textile manufacturing supply chain, other order qualifiers may include quality, lead-time and service level (Christopher & Towill 2001; Hill 1993).

Appendix A2 summarises different downstream perspectives towards cotton eco-labelling with key findings as follows:

- A 'premium-free' philosophy dominates the downstream driven cotton labelling schemes
- Farmers do not receive specific financial rewards for becoming sustainably labelled, they are seen as already benefiting from better knowledge, improved efficiency and yield
- Responsible cotton buyers and their downstream stakeholders have already 'subscribed' to eco-labelled cotton products by paying membership fees under various labelling schemes
- Cotton sustainability premiums are opportunistically leveraged by intermediaries when arriving overseas market for short-term financial gains; the increased purchasing costs are then passed on further downstream to the arm's length processer/manufacturer chains
- Fully integrated cotton firms do not consider the costs associated with becoming certified to be substantial, and prohibit any premiums to exist internally or be charged to brand retailers
- There are no strong indications that downstream stakeholders are willing to tolerate higher premiums associated with cotton sustainability labels now or in the foreseeable future

"Charging premiums has become a widely accepted practice and no one has a solution."
– A Chinese cotton importer reflecting on the 2014 BCI Supply Chain Event in Shanghai.

2.3.2 Australian growers perspectives on myBMP premiums

Most interviewed Australian growers do not hold the view that myBMP labels are currently able to generate premiums for average cotton farms. Some experienced cotton growers have remained sceptical about the industry's product differentiation strategy even if myBMP program is now collaborating with other eco-labelling schemes such as BCI and Cotton LEADS.

There are other Australian growers selling directly to the overseas markets who have established relatively stable business relationship with some sustainably accredited overseas trading houses. Compared to average growers, they are more likely to be informed about the downstream market dynamics surrounding myBMP and various other cotton eco-labels. Interestingly, the more informed Australian growers were not yet considering adopting myBMP. Table 2.3 below highlights some of the reasons extracted from our preliminary discussion with their overseas offices.

Table 2.3: Factors prohibiting informed Australian growers from adopting myBMP

Some relevant questions	Barriers for myBMP adoption
Do growers know about the on-going premiums on sustainable cotton labels?	Yes they do. But the amount has been insignificant.
Is it worth becoming myBMP accredited growers?	No. The benefits do not nearly cover the costs associated with adoption.
Do growers feel the need to become myBMP accredited?	Not much. For example, some neighbouring farms who are actually using 'inferior' production processes became myBMP accredited. The growers perceived joining myBMP would not enhance their farm credibility.
Is myBMP important for marketing growers' cotton?	Not likely. myBMP is a very small niche segment that has been fully satisfied by only a few Australian players.

In the open market where Australian grown 'BCI' cotton (i.e. myBMP) is traded internationally, we found evidence that some intermediary firms explicitly quoted 'BCI plus 2.00 *USc/lb*' on various Australian cotton grades including 'Oble', 'Andy' and 'Nice'[7]. Others firms in our sample requested telephone enquiries for buying Australian BCI which implicitly suggested differential pricing between myBMP and normal Australian cotton. Our sample consists of both small-to-medium sized as well as big-four cotton merchants.

[7] Sampling date 14th August 2014.

3. Managing Cotton Sustainability Tensions

3.1 Tensions around cotton sustainability

So far, we have provided some evidence on the difficulties for average cotton growers to create and capture value from their myBMP credentials. It is reasonable to assume that this will hold true for the foreseeable future.

> ***Focal Issue A: Australian cotton growers' costly investments into myBMP are unlikely to be financially compensated by the current Australian cotton value chain.***

On the other hand, the Australian cotton industry can be seen as under ever-intensified government and stakeholder scrutinies over its environmental management practices. Because most cotton growers are not myBMP accredited on a continuous basis, the industry does not have on record, the necessary information or alternative instruments to demonstrate its environmental credentials. One challenge is for the industry to secure optimal stakeholder relationships and social licence to operate[8].

> ***Example****: The Murray-Darling Basin has been consistently singled out and monitored at the United Nations level for its high water stress levels as well as its exemplar geopolitical location within a southern hemisphere advanced economy. Agriculture is deemed to be the main driver of the water issues, and cotton is officially listed as having the highest water footprint among different crops. Many Australian and international stakeholder groups are holding the Australian cotton industry responsible for contributing to the depletion of fresh water resources and damage to eco-systems in the Murray-Darling Basin. The industry needs proper and on-going responses to such charges.*

> ***Focal Issue B: The Australian cotton industry needs continuous investments into myBMP so growers' environmental management credentials are adequately developed and demonstrated.***

When they are seen individually, both A and B appear to be logical and reasonable. However, when the cotton industry is forced to face two issues simultaneously, their inherently inconsistent characteristics make the tensions between A and B not easily reconcilable or dealt with.

[8] WWAP (2009, 2012, 2014)

3.2 How to dissect the cotton sustainability-related tensions

We expect elements of sustainability related tension to be inherently contradictory to each other and on-going, which cannot be resolved in the foreseeable future. Given the stringent environmental regulations and high operating costs in Australia, experienced Australian growers can be seen as already being both financially and environmentally aware. As tensions escalate, growers' capacity to handle conflicts may be complemented by a well-planned conflict resolution pattern tailored for myBMP, which may be currently lacking.

The first step is to re-categorise elements of myBMP according to various value chain stakeholder demands. Table 3.1 below is presented for illustrative purposes.

Table 3.1: Start unpicking myBMP tension points

Driver	Benchmark	myBMP categories	Resource Provider	Funding Mechanism
Efficiency	Current costs	Cost savers	Grower	Pays itself
Market	e.g. BCI	Basic market requirement (covered by myBMP)	Grower	Part of on-farm production costs
		Additional market requirement (non-myBMP)	BCI	Training and verification funds from BCI
Local community	Prioritised essential community concerns	Social license to operate (in excess of BCI)	Cotton Value Chain Stakeholders	Value chain participants levy contribution
Scientifically defined sustainability	More advanced myBMP	Scientific requirements (multiple levels)	Wider Communities	Social benefit bond[9], government direct assist and/or tax benefit

[9] Social benefit bond is a new kind of financial instrument that "provides access to private capital to pay for public services" (The Centre for Social Impact, 2012). The public sector pays interest yield to bond buyers when an agreed social outcome is achieved by the private sector. This can be potentially used to finance farming sustainability development. Katsigiannis, Agarwal and Jin (2014) discusses its first use in NSW.

Apart from legal requirements and cost savers, other elements of myBMP will give rise to conflicts so long as the market is not compensating associated costs. Rather than forcing growers to absorb the full costs of becoming myBMP accredited, a better alignment of myBMP, stakeholder priorities and funding mechanisms is recommended. Secured finance flows may rejuvenate growers' interest in adopting certain elements of myBMP, while the industry explores other ways to maintain growers' financial viability as they continuously shift into higher sustainability requirements.

3.3 An on-going dynamic resolution for managing farming sustainability tensions

To deal with complex tensions and conflicts, the cotton industry may need purposeful and repeated strategic responses (Clegg 2002; Smith & Lewis 2011). More specifically, an on-going dynamic resolution involves the integration of the most prioritised elements from both sides of a conflict, with the remaining and emerging conflicts dealt with in the next round and so on. This iterative cycle repeats indefinitely since sustainability related tensions are expected to persist into the future.

Such a compromise-based approach is potentially useful for overcoming the growers' initial psychological and/or financial barriers to adopting myBMP. It encourages a virtuous cycle of problem solving and adaptation which is important as the industry faces increasingly volatile and unclear external environments. Figure 4 below illustrates a template for the processes involved.

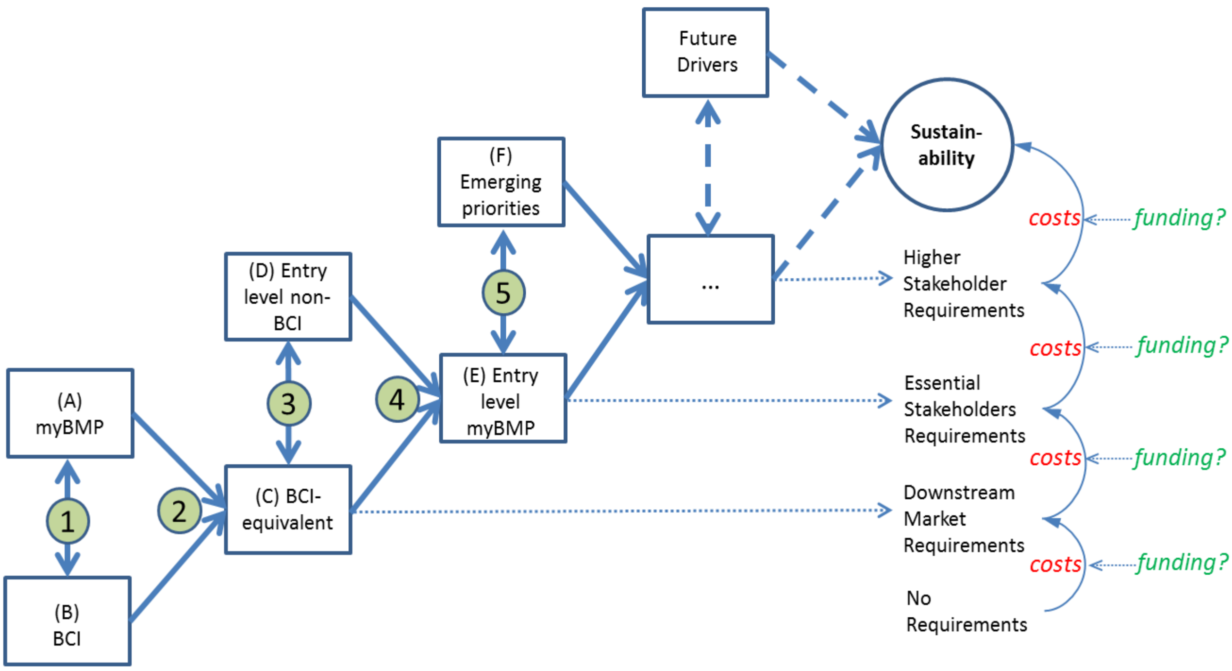

Figure 3.1: An illustration of the on-going dynamic resolution of sustainability related conflicts

Step 1: To benchmark myBMP (A) against market requirements (B) e.g. BCI

Step 2: To synthesis most prioritised elements from (A) and (B) into downstream market requirements (C), e.g. 'BCI-equivalent'; set up viable funding mechanisms to finance growers' costs for achieving (C)

Step 3: To benchmark (C) against previously neglected entry-level myBMP elements (D)

Step 4: To synthesis most prioritised elements from (C) and (D) into essential stakeholder requirements (E), e.g. 'Entry level myBMP'; set up viable funding mechanisms to finance growers' costs for achieving (E)

Step 5: To benchmark (E) against previously neglected myBMP elements which became newly emerged priorities (F) as future unfolds

Why doesn't costly farming sustainability pay? How to make it pay?

Farming sustainability, differed stakeholder perspectives and difficulties to finance sustainability development are all complex issues that cannot be defined or expected to be managed in simple and straightforward ways. An on-going dynamic resolution allows the cotton industry to focus always on areas exhibiting higher probability of success, and to make tangible progress towards target.

So far in the report, we have maintained a pragmatic stand point. That is, will sustainability work for growers in real business sense and if not how to deal with it? Readers who are more interested in our practical recommendations may refer to Section 6 (page 32), where we discuss Target Costing and its potential for dealing with sustainability-related tensions and for enhancing the competitiveness of the Australian cotton industry.

In the next section (Section 4), we take a less pragmatic stance and discuss in more depth the underlying factors potentially enabling and/or prohibiting growers to directly compete using their sustainability credentials. The framework may be useful for industry decision makers who need to contemplate from a longer-term perspective. Some comparative case analyses from other premium priced eco-labelled cotton value chains are then discussed in Section 5 to complement the theoretical discussions.

4. Supply Chain Framework Development

Although perceived as controversial by some value chain stakeholders, we maintain that making sustainability work in a real business sense will be of significant strategic import for the future Australian cotton industry. The framework development presented here reflects some of our progress towards a deeper understanding of this complex phenomenon. In Section 4, we preview some of the relevant factors potentially enabling and/or prohibiting the achievement of Objective 1. Some comparative case analyses from other premium eco-labelled cotton value chains are then presented in Section 5. Readers who are more interested in our practical recommendations for the interim periods may refer to Section 6 on *Target Costing* (page 31).

What is sustainable competitive advantage?

Research in the strategic management literature has consistently shown that there is no optimal strategy to compete. Instead, superior performance is driven by having a better fit between the organisation's strategy and its internal (e.g. administrative) and external (e.g. market) structures (Zott and Amit, 2008). This view is consistent with the leading research in supply chain management, which argues that in today's volatile business environments, competitive advantage will be largely determined by how well an organisation's supply chain structure is aligned with downstream dynamics, when compared with competing supply chains selling into the markets (Gattorna, 2010).

Our framework development is based on the premise that competitive advantage can be seen as matter of *supply chain fit*. To continue this line of argument we need to articulate at a more fundamental level why growers and buyers structure their businesses along the cotton value chain in certain ways. The basic building blocks for such a model are farmer's and buyer's strategic positions towards each other, and the inter-firm transactions that make up the linkages between them.

4.1 Grower's product market strategy

A product market strategy can be seen as the way in which a cotton farm chooses to position itself advantageously against competition in the downstream marketplace. This entails the identification and leverage of a set of drivers of customer demand. At a high level, demand drivers can be summarised into price (cost to customers), functionality (the technical fibre specification by design), quality (actual fibre performance upon delivery) and timing[10]. In order to leverage these drivers,

[10] Cooper & Slagmulder (1997).

traditional strategy literature prescribes the choice of adopting the **cost leadership** and/or **differentiation** product market strategies (Porter, 1985).

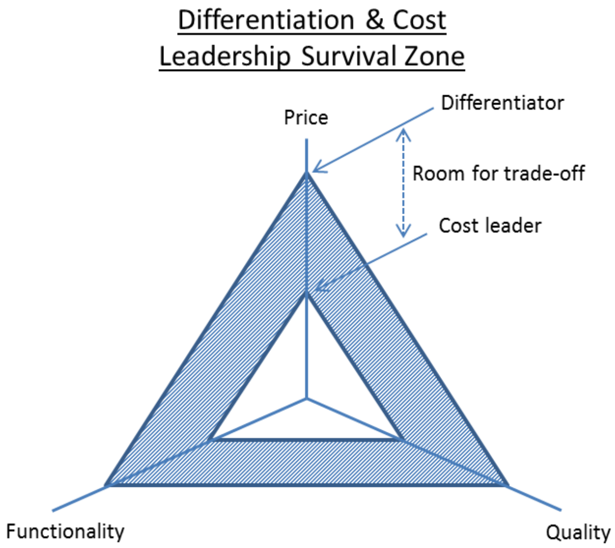

Figure 4.1: The traditional competition survival zone, adapted from Cooper & Slagmulder (1997)

A three dimensional cost-functionality-quality 'survival zone' (Figure 4.1) is helpful for describing the grower's product market positioning. The Australian cotton industry can be seen as pursuing a differentiation strategy which depends on the customer's willingness to tolerate higher purchasing prices for superior fibre functionality and quality. On the other hand, cost leaders such as the Brazilian cotton industry enter the market at similar timing with lower quality but lower cost.

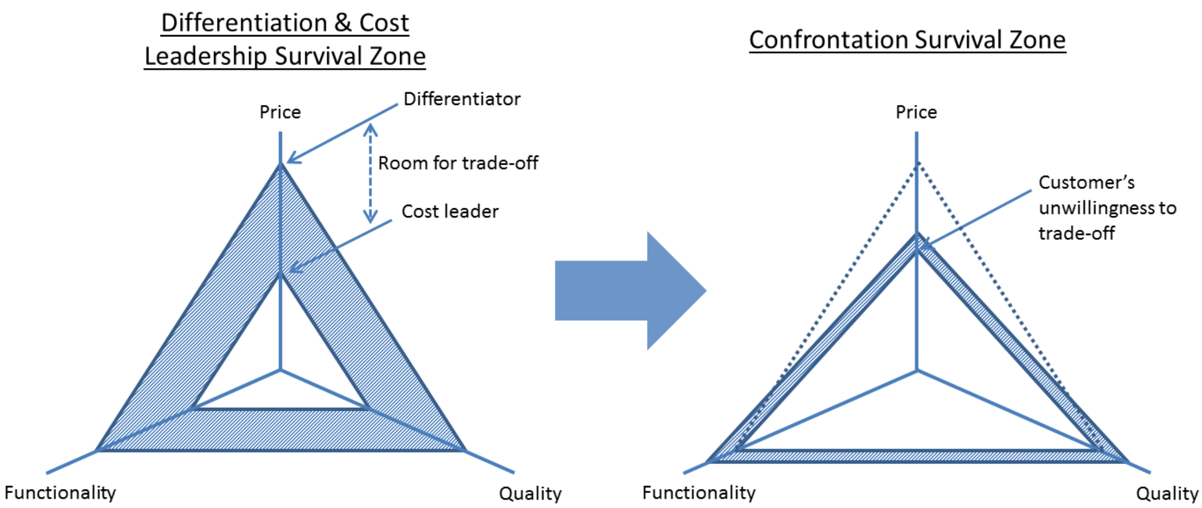

Figure 4.2: Confrontational competition survival zone, adapted from Cooper & Slagmulder (1997)

One trend (especially for myBMP and other eco-labels) is that competition is shifting towards a confrontation survival zone (Figure 4.2) under which customers are demanding improved performance from all suppliers (e.g. entry-level sustainability requirements) but are increasingly unwilling to trade-off on purchasing prices.

When cotton sustainability credentials are commoditised and become widely available, the more expensive Australian myBMP fibre may have to compete head-on with equivalent labels attached to cheaper fibre such as Brazilian cotton (which customers will consider first for its cheaper price and arguably more positive social and environmental impacts), resulting in a disadvantageous competitive position.

4.2 Buyer's sourcing strategy

Mirroring the supplier's product market strategy towards downstream is the buyer's sourcing strategy towards upstream. Cotton is an important commodity which makes up a significant portion of the buyer's production cost, but at the same time it is widely available in the open market. Consistent with the traditional purchasing literature, cotton buyers can be seen as pursuing a 'Leverage' sourcing strategy under which the full exploitation of their bargaining power is recommended whenever possible, to drive down prices and hence sourcing costs (Kraljic, 1983).

This dominating approach has been influential even today, but one important adaptation is made by Pagell et al. (2010) who incorporated the sustainability concept into the original purchasing portfolio approach. This is illustrated in Figure 6 below.

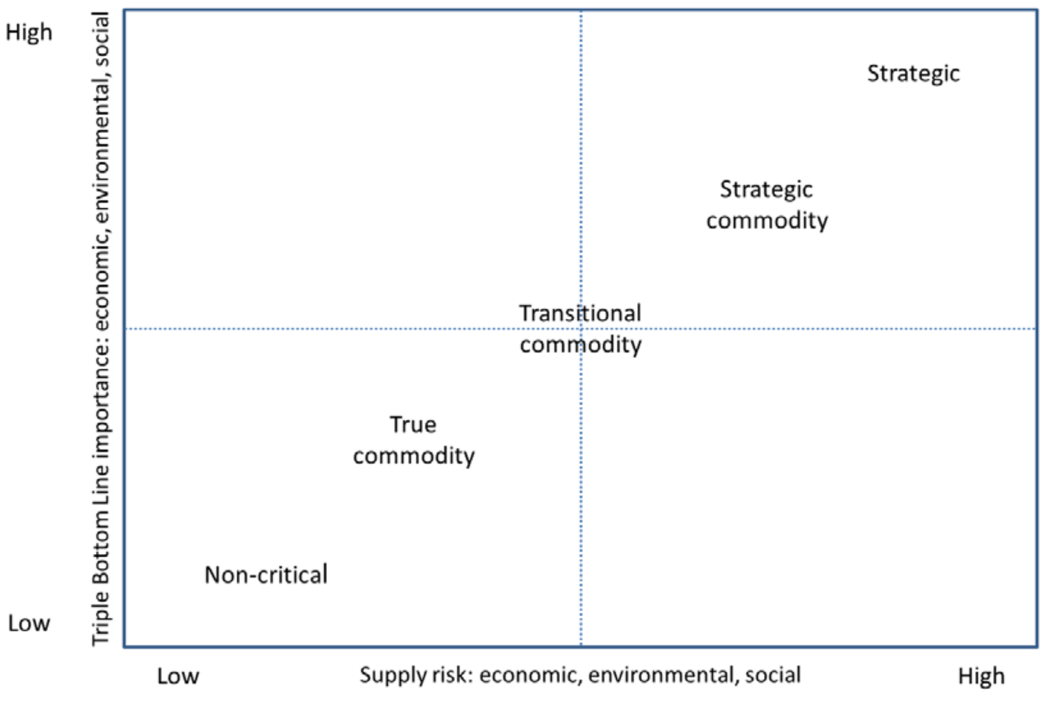

Figure 4.3: Revised Kraljic model: a sustainability perspective

Source: Reproduced from Johnsen et al. (2014), adapted from Pagell et al. (2010)

Extending beyond the short-term economic considerations, the horizontal axis now reflects supply risks as defined in economic, environmental and social dimensions. Similarly, the vertical axis now contains the potential negative or positive impacts on buyer's triple bottom line performance (economic, environmental and social) if certain cotton products are purchased.

Key predictions from the model:

- Cotton's sustainability credentials may allow certain fibre to become ***Transitional commodity*** for which buyer's 'Leveraged' sourcing strategy is restrained temporarily
- Transitional commodity tends to revert back to the ***True commodity*** status once cotton sustainability credentials become more commonly available
- It is unlikely that myBMP will become a ***Strategic commodity*** under the current market structure, without long-term strategic collaboration and relationship building with buyers

4.3 Value chain transactions – business model approach

A business model is "a structural template that describes the organisation of a focal firms' transactions with all of its external constituents in factor and product markets" (Zott and Amit, 2008). It reflects the conscious design choices a firm can make to achieve value creation and value capture within its value chain. Its main components are the *content*, *structure* and *governance* of the firm's transactions with external parties (Zott and Amit, 2007) [11].

At a high level, the firm's business model can be described as having one of the following alternative design themes:

- *Efficiency-centred business model*
  With an emphasis on lowering costs, an efficiency-based design theme reflects the firm's strategic intent to decrease transaction costs. As discussed in our Second Year Report, many average Australian growers do not consider post-farm gate value chain transactions to be part of their own business models. This can be explained by the efficiency rationale.

- *Novelty-centred business model*
  With an emphasis on innovative value creation (i.e. increasing the size of the pie), novelty-based design theme reflects the firm's strategic intent to expand and capture more value by establishing new connections with previously unrelated value chain components. The

[11] For more elaborated discussions around business model please refer to the Second Year Report (Part I).

number of external linkages is an important indicator for business model novelty. Reproduced below from our Second Year Report, the illustrative business model of some Texas growers exhibits a higher count of external business relationships and value chain transactions.

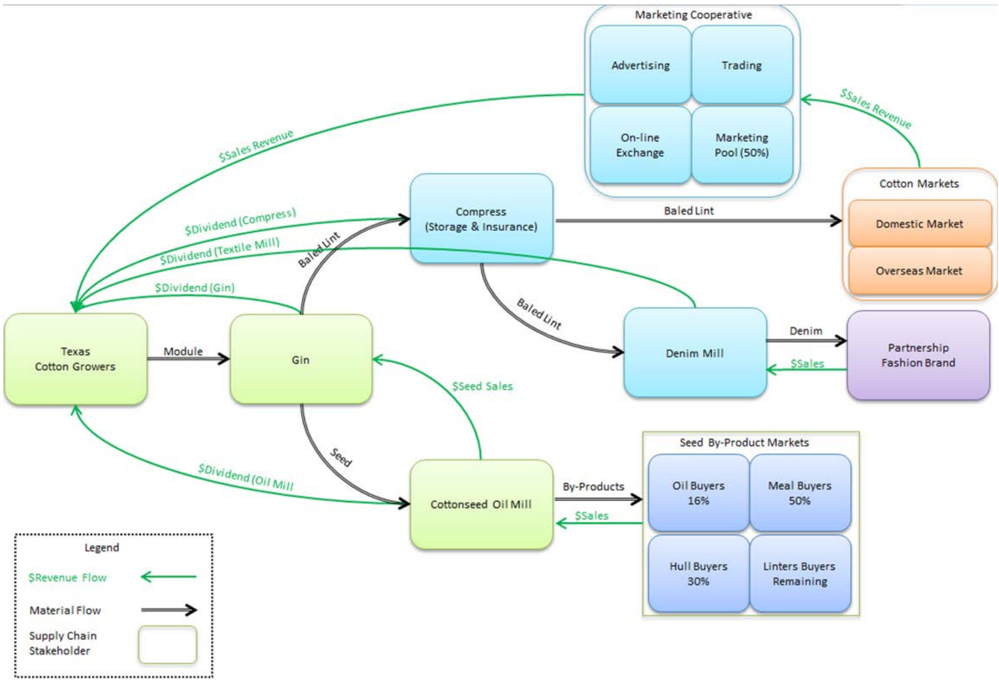

Figure 4.4: A novelty-centred business model reproduced from the Second Year Report

4.4 Grower-buyer relationship

The ***relationship*** between the grower and buyer of cotton is intimately related to their strategic stances towards each other, and how they conduct businesses along the cotton value chain. Competition, as described by the traditional economic frameworks, tends to narrowly define the business relationship as arm's length, rational and short-term opportunistic. However, this view is increasingly criticised by a more relational view which sees organisations as intrinsically interrelated with each other and competition is between rival supply chains not individual players or products. As we will illustrate later using comparative business cases, the way growers relate to the rest of the value chain can change which may lead to differing value chain performances.

One foundational model of supply chain relationship management was provided by Hakansson (1982), which may be useful for describing the nature and potential of grower-buyer relationship:

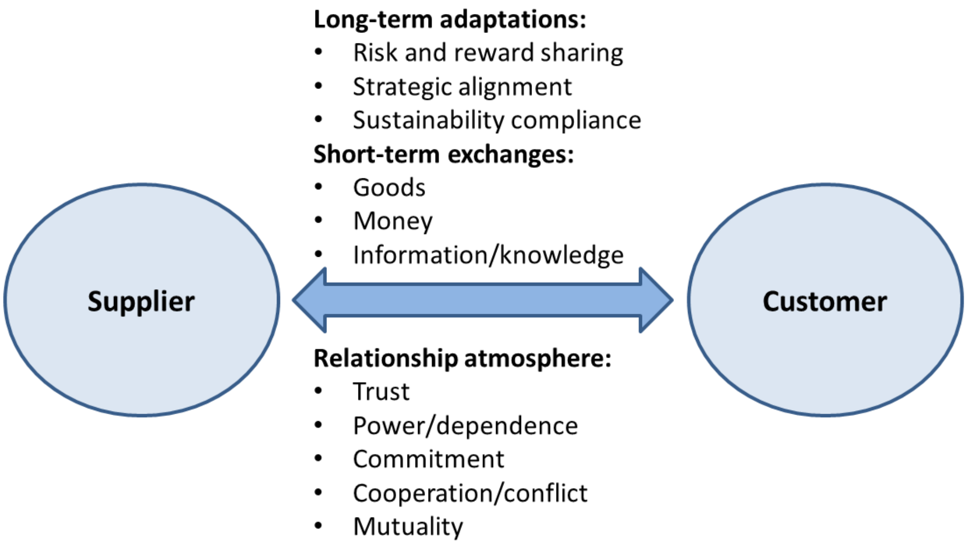

Figure 4.5: Supplier-Customer Interaction Model
Source: adapted from Hakansson (1982), reproduced from Johnsen et al. (2014)

By examining the business relationship in more detail, its influences on grower and buyer strategies may become more explicit to industry decision makers. This may have important implications for the industry's objective to leverage cotton's sustainability information for improved downstream performance. It is possible that some specific characteristics of business relationship may be essential for the development of alternative cotton value chain architecture. For example, risk and reward sharing, strategic alignment, trust and power balance between growers and other value chain participants. Although these are not common in the Australian cotton value chain, the case studies in Section 5 demonstrate that alternative relationships were possible in other cotton chains.

4.5 Towards an integrated value chain framework

Research in the strategic management literature has examined the fit between a company's product market strategy and its business model designs, and the degree of fit is found to impact the firm's financial performance (e.g. Zott and Amit, 2008). We suggest that this logic of structural fit may be useful for developing a prototype theoretical framework which may link multiple strategic elements of cotton value chain to each other in a coherent and sensible way.

The main message from our market analysis in Section 2 is that the product market strategy to differentiate Australian cotton using myBMP credentials is unlikely to yield substantial grower value. However, the ineffectiveness of myBMP differentiation strategy (a particular product market strategy) needs to be understood within a broader context occupied by other relevant value chain and external factors.

In an elemental supply chain (top layer) we recognise the cotton grower, cotton buyer and the linkages between them. Growers need to transact with buyers from whom some revenue can be generated back to farm-gate. However, how organisations market or purchase sustainable cotton concerns the corporate strategy level. To explain why certain strategies may or may not fit we need to assess at a more fundamental level their corporate maturity (medium layer). In other words, how far the organisations have incorporated the concept of sustainability into their core businesses or 'corporate sustainability phase', and how mature the business relationships between them are, will have a significant effect on how growers and buyers position themselves and deal with each other on the first layer. The above factors are also influenced by forces external to the value chain participants (bottom layer), which can be seen as indirectly shaping the cotton value chain into certain structures instead of others.

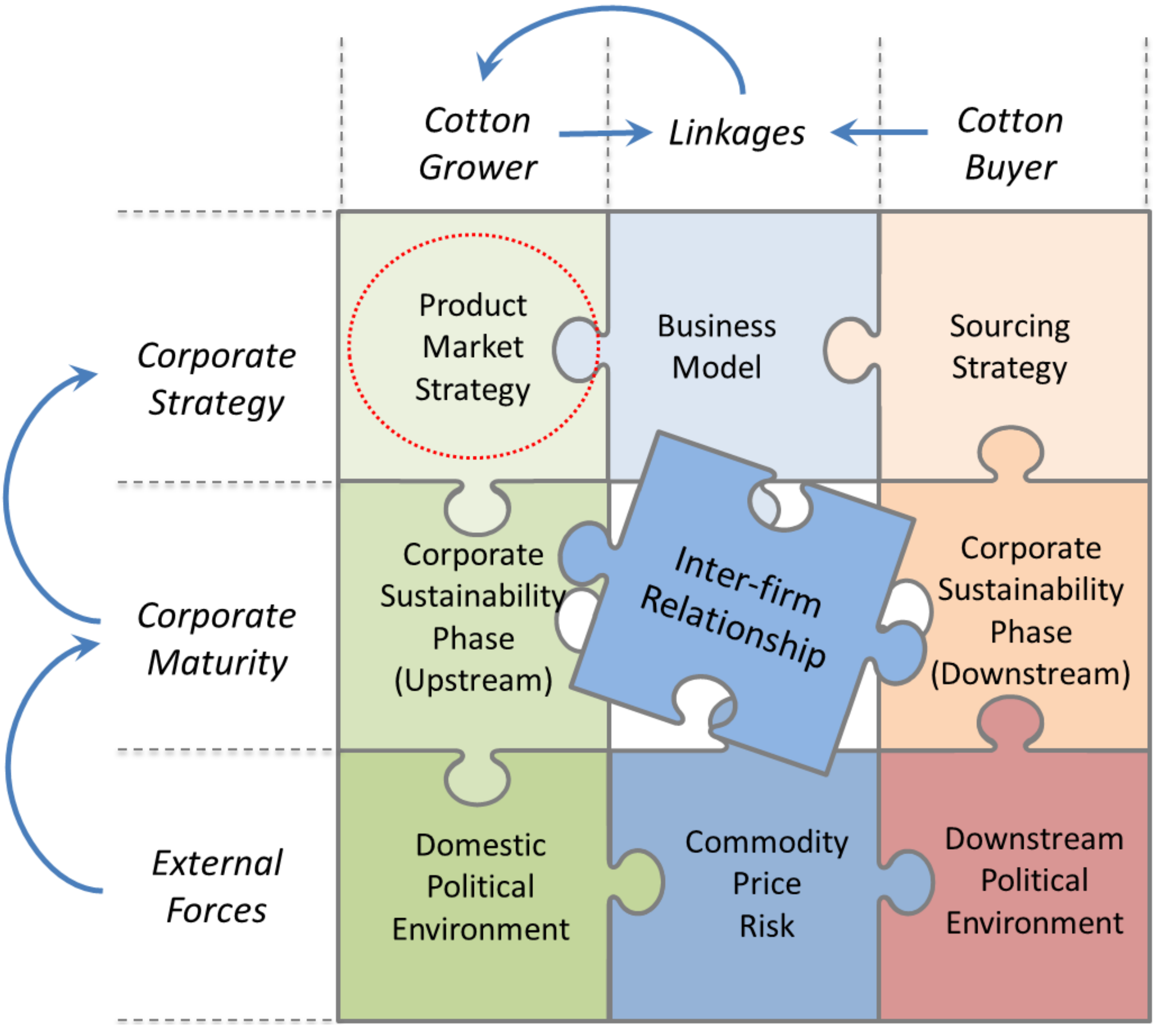

Figure 4.6: An illustrative example of a strategic value chain framework[12]

[12] The model components are presented for illustrative purposes and may be subject to further changes.

Following this framework, some myBMP related challenges can therefore be summarised as:

- When a cotton buyer's sourcing strategy treats myBMP cotton as a transitional/true commodity, the freedom for price leverage is limited/non-existent
- When a grower's business model focuses on efficiency instead of establishing further downstream linkages, the chances of creating and capturing new myBMP value are reduced
- Australian farms are ahead of overseas buyers in terms of their corporate sustainability development phase, and cotton buyers in general are not under significant pressure to incorporate true sustainability into their core businesses or to give above-market rewards
- The gap between upstream and downstream sustainability development is expected to persist if sustainability only remains a national priority in Australia but is less clear under the opaque overseas regimes[13]
- Most factors, including the need to manage commodity price risks, are currently prohibiting the establishment of longer-term, more strategically oriented business relationships between Australian growers and cotton buyers (e.g. low risk and information sharing), which may be essential building blocks for alternative value chain architectures

The purpose of this framework development is to set some foundations for a better explanation of why on-farm sustainability development will or will not work for growers in a real business sense. Although it is still in its early stage and the factors discussed are far from exhaustive, it is clear that many changes are needed to overcome the challenges. Furthermore, these changes cannot be successfully initiated or handled by Australian cotton growers alone.

Next, we compare characteristics of the Australian cotton value chain with alternative eco-labelled cotton value chains identified in the business literature as examples of premiums being enabled and obtainable by growers under distinctively different value chain architecture arrangements.

[13]The downstream political environment is unclear in regards to prioritising cotton sustainability. For example, despite its widely criticised unsustainable production processes, Uzbekistan remained one of the major exporters in the Chinese market. According to several Chinese trading houses, Uzbek cotton is exclusively marketed through the non-market political channels featuring a 'strategic' collaboration between the two governments. Furthermore, certain Chinese mills are given incentives to purchase and use Uzbek cotton. In contrast, genuinely more sustainable Australian cotton is unlikely to receive favourable political treatment overseas as the Chinese government shifted from foreign imports towards stimulating domestic consumptions.

5 Comparative Premium Cotton Value Chains and Case Analysis

5.1 Australian Cotton Value Chain

Figure 5.1 illustrates the nature of the current myBMP supply chains.

Main Characteristics:

- Australian cotton farms and highly visible brand retailers are under pressure to deliver sustainability performance at the two far ends of the supply chain
- The demand for myBMP information is currently driven by Brand Retailers who initiate the formation of the temporary chain by placing orders specifying the volume of BCI usage
- Average cotton growers are not exposed to information or finance flows associated with myBMP labels
- Merchants sell myBMP into downstream BCI (or equivalent) supply chains where some premiums may exist
- Rational mills and later stage processing companies may tolerate some premiums during bargaining, which are then recovered from their own downstream transactions
- Brand retailers ultimately bear the additional costs associated with myBMP premiums which they could not effectively recover from end consumers

Key Issue:

- The myBMP supply chain is highly fragmented with linkages between adjacent supply chain actors made up by opportunistic price bargaining in the open-market
- The growing and retailing sectors are under stakeholder pressures to incur more sustainability related costs without adequate financing mechanisms to pay for the associated costs
- The overseas processing sector firms can be seen as passive (some may be ignorant) agents of sustainability development; they are rational agents who make value chain decisions on cotton eco-labelling following short-term opportunistic economic rationale
- The supply chain has no hierarchical coordination by identifiable actors
- No longer-term strategic business relationship has been formed between supply chain actors;
- Lack of driver for significant change and adaptation for the myBMP value chain

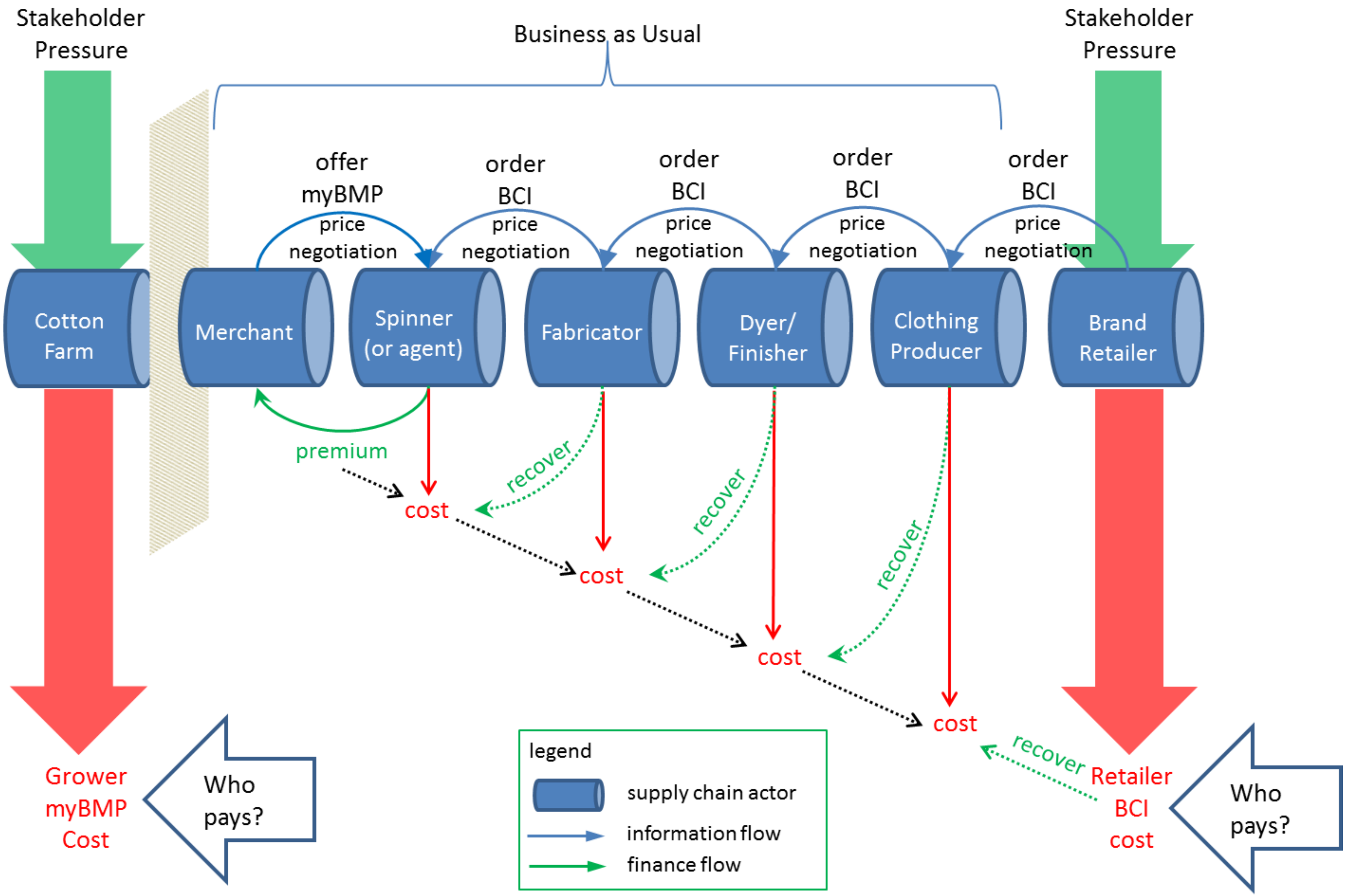

Figure 5.1: The current supply chain structure for the myBMP label

5.2 Other premium eco-labelled cotton chains[14]

5.2.1 Initial supply chain barriers and needs for structural change

Common to all three cases, is that a focal firm had perceived a downstream pull and the opportunity to differentiate themselves by using responsibly grown cotton fibre[15]. Another similarity is that despite their initial strategies, all three focal firms had to actively restructure their cotton supply chains to make the premium-responsible business strategy work.

The changes were driven by a number of common barriers in traditional cotton supply chains:

Problem 1: First of all, cotton supply chains are fragmented spanning over long geographic and market distances. They consist of self-interested stakeholders rationally optimising their local positions at multiple supply chain touch-points. ***Therefore, there is a need for some resourceful actors to actively drive supply chain collaboration and coordination.***

Problem 2: Cotton growers interact with post-farm-gate supply chain using arm's length spot market exchange. Under such arrangements the costs associated with changing farming practices and affected yield are unlikely to be compensated. Initially there was limited supply of premium responsible cotton and ***therefore there is a need to incentivise growers' commitment***.

Problem 3: Cotton supply chain stakeholders are price sensitive. Using responsible cotton involves additional costs associated with changing farming, processing[16], certification and other administrative duties[17]. Costs are added at each stage of the supply chain as firms aim to maintain margins, impacting the competitiveness of the whole chain. ***Therefore, there is a need to reduce supply chain transaction costs***.

Problem 4: End consumers make purchasing decisions based on product's relative competitiveness involving costs and benefits. Responsible cotton products need to offer real value-added to justify the premium prices. ***This requires the functioning of sophisticated retail marketing channels.***

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[14] Please refer to Appendix A4 for a more detailed comparison analysis based on a business model framework adapted from Demil & Lecocq (2010).

[15] The scientific debate on the environmental credentials of organic cotton is beyond the current scope.

[16] For example, compulsory segregation of processing and warehousing areas and loss in efficiency due to smaller batches.

[17] This is consistent with the current downstream BCI/myBMP supply chain where Chinese processors need to maintain internal monitoring and documentation, as well as to cooperate with external audits.

5.2.2 Adapted supply chain structures and coordination mechanisms

The exemplar supply chains have overcome the abovementioned barriers by:

Solution a: Focal firms either voluntarily or passively realised the need to reconsider their relevant roles in the cotton supply chains. Supply chain stakeholders from growers to downstream were exhibiting low commitment and lack of expertise in operating the new premium-responsible cotton products. The focal firms therefore assumed additional administrative and operational responsibilities that were traditionally held by other supply chain stages. This ***overarching coordination by a focal firm***, at least during the chain's early developments, was found to be crucial (Agarwal & Subramani, 2013; Goldbach et al., 2003).

Solution b: No firms had adequate resources to orchestrate the entire supply chain operations. Closely related to the first decision was ***a strategy to shorten the cotton supply chain via improved processes and integration***. The focal firms were found to reduce the number of supply chain intermediaries and to facilitate supply chain negotiations and transactions in other touch-points. Shortening the cotton supply chain was essential for effective cost management. This allowed the chain to, on the one hand guarantee stable and premium prices paid to cotton growers and other suppliers; on the other hand, the overall supply chain cost is under control which led to a final premium product still competitively priced in the sensitive marketplace.

Solution c: ***The unstable arm's length relationships between supply chain stakeholders were replaced by more stable strategic partnerships.*** This was argued to be driven by shifts at a philosophical level in regards to how the focal firms believed the cotton supply chains should operate (Meyer & Hohmann 2000). Closely related to *Solution a and b* above, the focal firms decided to narrow down their potential supply chain counterparts and approached them with a clear intention to establish collaborative partnership relationships from a long term perspective.

Solution d: Instead of relying on the opportunistic spot market pricing mechanisms, the focal firms had put in place ***dedicated finance flows to incentivise and support the on-going operations of cotton growers and other suppliers.*** The contracts used to coordinate supply chain activities were longer-term in nature which specified above-market premiums guaranteed to growers and other suppliers. An on-going premium cash flow was viable due to the cost savings achieved in *Solution b.* In addition, some focal firms also used dedicated funds to finance growers' transition costs into new farming practices.

These resulted in a different value chain structure as depicted in Figure 5.2 below.

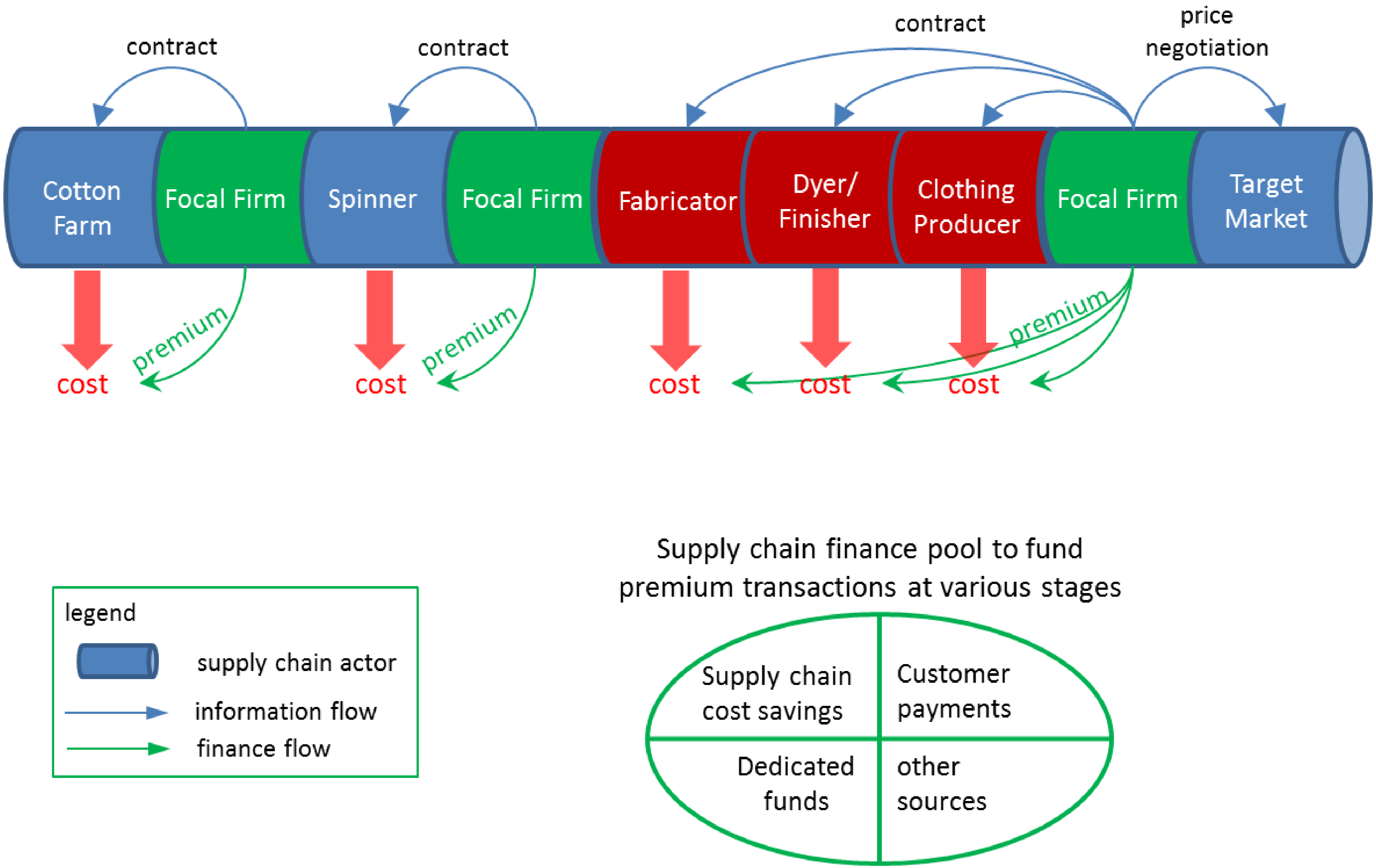

Figure 5.2: Illustrative premium-responsible cotton supply chain structure

6. Practical Recommendations for a Transitioning Cotton Industry

6.1 Target costing as an alternative supply chain strategy

The ***Target Costing*** (or TC) framework begins by assessing the customer's willingness to pay, and holds the estimated selling price to be given (Carlsson-Wall & Kraus 2010). Target Costing assumes a narrow survival zone which features higher base-line functionality and quality requirements of the product, but is less tolerant for higher prices[18].

$$\textit{Estimated Selling Price} - \textit{Desired Profit} = \textit{Target Cost}$$

Under such an approach, growers need to make explicit their desired profit levels that may satisfy grower's required return as shareholders in the farming business (cost of equity capital), and to compensate for financing costs (cost of debt capital). By deducting the 'target' profit from a realistic selling price of cotton, growers may arrive at the allowable target cost, the cost pool which in principle cannot be exceeded while planning and running the cotton business. If implemented successfully, it secures a certain level of grower profitability even under unfavourable market conditions, while allowing growers to take advantage of potential upside market risks[19].

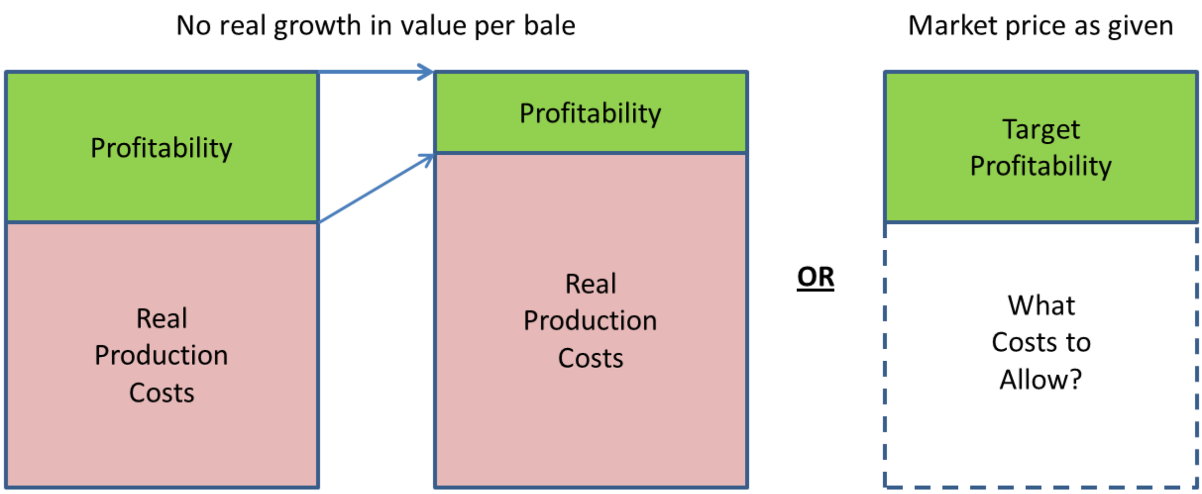

Figure 6.1: Profit as Outcome vs. Profit as a Target

[18] Evidence of steady value per bale and increasing farming costs is available from Boyce (2012).

[19] For example, the recently abolished Chinese reserve policy has arguably contributed to higher than expected cotton prices for a period of time. This can be seen as an upward price risk which is temporary, and for cotton producers who have been successful in maintaining their costs, exceptional premium returns should be expected for the same period of time. On the other hand, when Chinese government announced the significantly reduced import quota for foreign grown cotton, lower cost cotton growers may still survive while the price levels become financially unviable for other higher cost growers.

6.2 Implementing target costing in cotton supply chain

Figure 6.2 below depicts a general framework for applying target costing in cotton supply chains. The top row represents the target costing formula discussed earlier from which the allowable costs are derived. The level of allowable costs needs to be committed by the producer which is not to be exceeded. If there is a gap between the target cost and the producer's current cost, it becomes the strategic cost reduction challenge.

The overall cost reduction target is cascaded down into three dimensions:

- ***Product-level target costing*** concerns the supply chain's direct material costs of producing certain cotton. On-farm, most growers make early decisions on what to grow, that is cotton with pre-determined specifications and potentially myBMP accreditation. Therefore, cotton growers can be seen as committed to substantial material costs (e.g. certain seeds or more environmental materials that have to be used) even before planting. Within the supply chain context, growers' suppliers and post-farm-gate processors/merchants will also incur direct material costs by committing to supply and move certain cotton products, such as inputs for making new seeds or any specialised equipment or materials for processing certain cotton.
- ***Process-level target costing*** concerns the activity costs involved on-farm and in other parts of the cotton supply chain. These are the costs of performing necessary activities, for example growers' certain production processes as specified by downstream BCI plus the other entry-level myBMP requirements. Growers' suppliers and ginner/merchants will also incur activity costs by performing certain processes such as R&D, dedicated production set up for certain fibres, and their transportation or warehousing post-farm-gate.
- ***Transaction-level target costing*** concerns the costs growers and other supply chain stakeholders incur while dealing with each other during business transactions. These are usually driven upwards by having more intermediary touch-points, as multi-staged price discoveries and bargaining activities introduce more costs to the supply chain as a whole.

Value engineering aims to recognise and measure in financial terms the relevant costs in each category, and to make necessary trade-offs and reconfigurations so the overall strategic cost reduction target can be met (Cooper & Slagmulder 1997). This is an *aggressive* stance towards supply chain cost management which requires collaboration and information sharing from all supply chain stakeholders who share similar strategic objectives. By correctly assessing and distributing cost pressures to key supply chain stakeholders, innovations are encouraged as firms explore new ways to reduce industry costs while maintaining market satisfaction. If a more stable profitability can be achieved under TC, the future cotton industry may become more competitive by its very design.

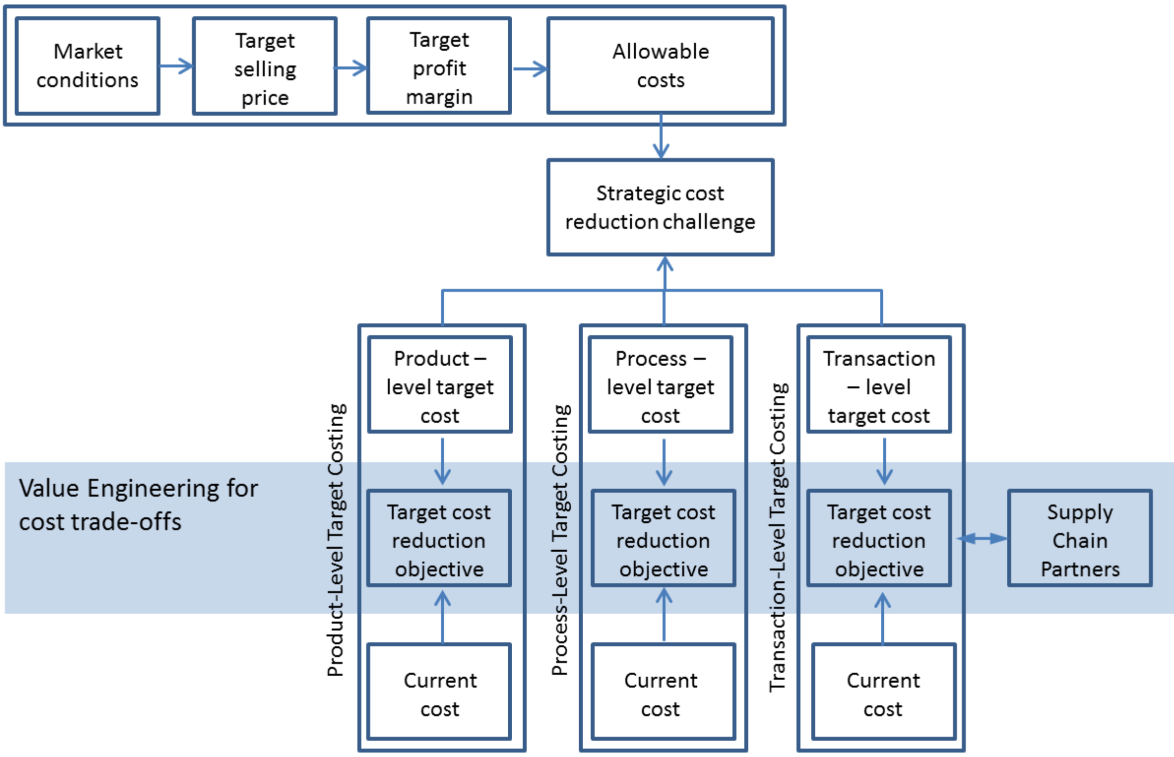

Figure 6.2: Supply Chain Target Costing and Value Engineering Adapted from (Cooper & Slagmulder 1997; Seuring 2002)

Target costing has been adopted to manage cost in man-made-fibre supply chains[20]. The highlights during their TC adoption and implementation are:

- The increasingly dynamic and challenging market conditions presented a compelling case for the fibre supply chain stakeholders to join forces as orchestrated by brand retailers
- Supplier-buyer relationship shifted from arm's length towards strategic collaboration with balanced power distribution (as measured by relative market dependencies)
- The target selling price was defined by fibres of comparable quality available elsewhere[21]
- The main cost items considered were adjustable technical and administrative processes
- Changed product specification (e.g. increased quality) were having greatest impacts on producers' costs, but less so in later stages such as spinning and no impact to retailers
- Direct material cost savings were limited even when production was optimised at all stages
- Process-level cost savings were achieved by having economies of scale featuring less product variations and larger production runs (e.g. less switches or set ups at processing plants)
- Transaction-level cost savings were achieved by: (i) an integrated supplier free of intermediaries was chosen to deliver the new fibre products; (ii) traditional fibre purchasing volumes were stabilised at downstream to improve other suppliers' planning and efficiency

[20] For more details please refer to Seuring (2002).
[21] In the case of myBMP labels, the industry may consider non-premium price levels such as '0' which means all necessary costs need to be absorbed by the new supply chain as a result of value engineering.

6.3 Concluding remarks

Target costing opens up new avenues for growers' cost reduction which is intimately linked to cotton farm's long-term survival. Although its adoption and implementation may encounter many challenges, transitioning to a more ***collaborative relationship*** between growers and other value chain stakeholders is identified as a main barrier and therefore a key success factor going forward.

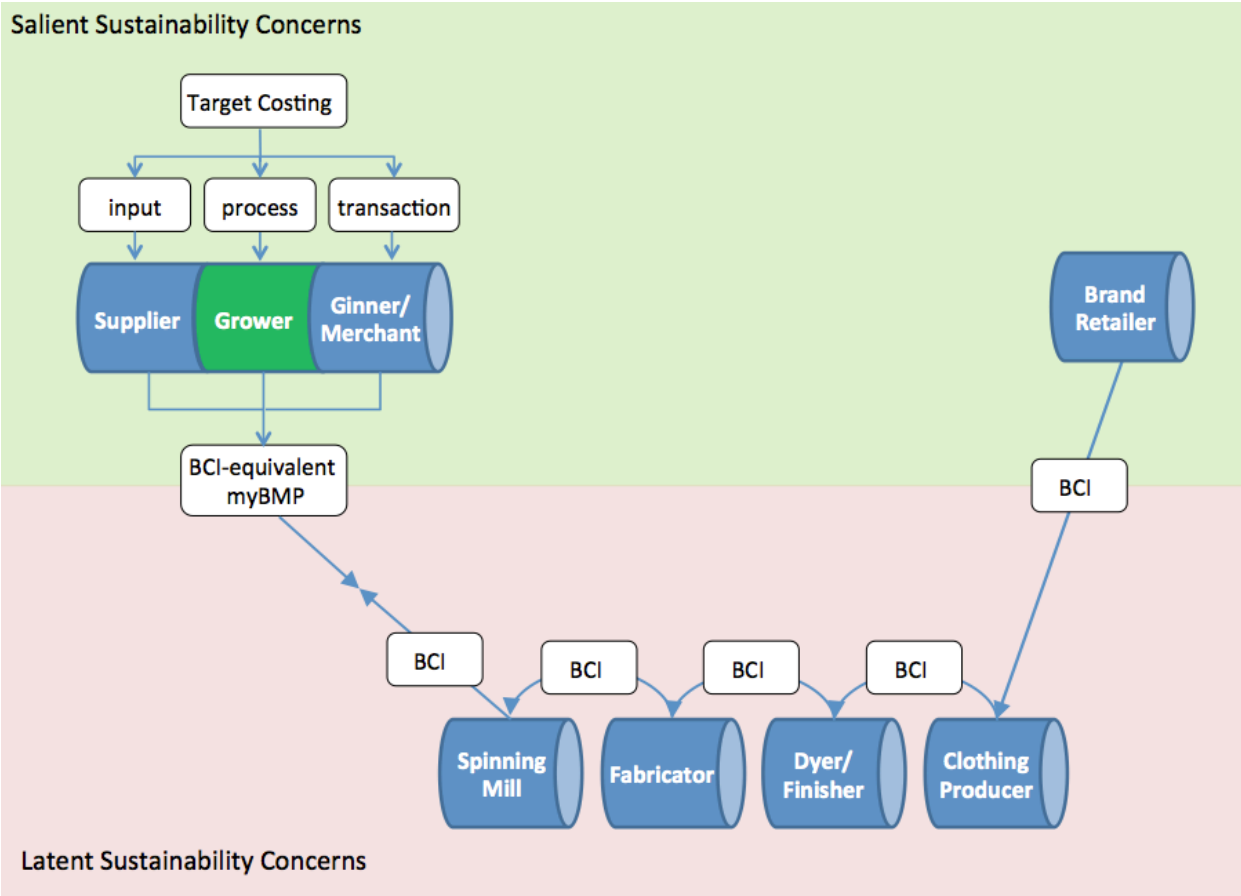

Figure 6.3 An illustrative Australian cotton value chain as structured by Target Costing

Other cotton industries responded to growers' declining margins by having more drastic value chain restructuring. For example, with financial backings from venture capitalists and the expertise of a formal 'ABCD' commodity trader Adrian Moguel, 30 big farming groups in Brazil formed Libero Commodities which now handles most of the Brazilian cotton produce. As downstream markets such as China shift towards integrated 'big-scale' demand, the Brazilian cotton industry responded with integrated 'big-scale' supply, eliminating 'suboptimal' industry fragmentations and intermediaries[22].

With cotton sustainability labels increasingly being commoditised and supplied by lower cost industries elsewhere, any potential advantages of myBMP label can be expected to be leveraged by competition. Instead, target costing offers the cotton industry a way to respond to more aggressive value chain architectures, while maintaining the sovereignties of various cotton stakeholders.

[22] Carpenter (2009); Fortson (2010)

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Appendices

Appendix 1 Economic analysis on the market structure for responsible cotton

For the purpose of this economic analysis, we see sustainability credentials as a newly emerged cotton product attribute that cannot be satisfied by other traditional cotton fibre. We assume that the current market structure features many cotton suppliers offering products that are not perfect substitutes. For example, there may be physically comparable cotton fibres competing in overseas markets but only some are accredited with BCI/myBMP labels. The analysis provides an overview of the market dynamics surrounding cotton sustainability credentials in general, instead of discussing the competition between alternative eco-labelling schemes. Therefore, cotton products under various sustainability labelling schemes are assumed to perform similarly under the same economic framework. This assumption is consistent with the current trend of consolidation of various schemes. The outcome of our analysis is also sense-checked with other evidence (e.g. downstream stakeholder interviews) and the assumption generally holds[23].

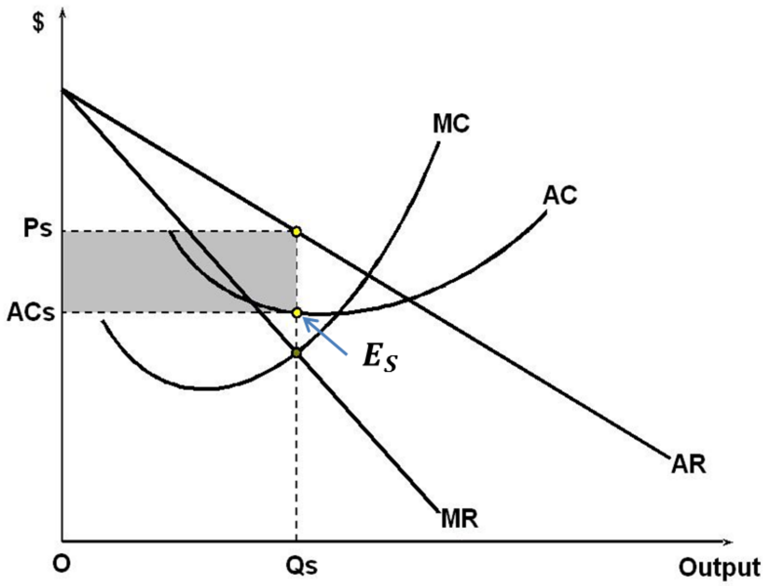
Short-term equilibrium

Brand retailer's commitment to a certain amount of eco-labelled cotton triggers the following economic activities. Because mill customers need to use specified amount of eco-labelled cotton to satisfy downstream client orders, there is a market demand as represented by the two downward pointing revenue curves MR and AR, as depicted in Figure A1 below. On the other hand, the supply forces are represented by the two concave cost curves MC and AC. The concept of 'marginal' or incremental change is used to locate the optimal quantity and price point for maximum profit. More specifically, point E_S (short-term equilibrium) is where suppliers' marginal cost equals their marginal revenue (that is, by selling one more unit of the product the supplier incur equal amount of cost). This is the point beyond which suppliers incur losses by producing more output (MC now sits above MR).

At E_S, the difference between suppliers' actual cost (AC, average cost per unit) and their actual revenue (AR, average revenue per unit) is the price premium on eco-labelled cotton. By multiplying

[23] Cotton made in Africa (or CmiA), due to its more demanding membership fees structure (charging certain precent of the organisation's revenue) is seen as being comparatively more expensive to buy in the open-market. However, informants at the overseas trading houses expressed concerns in regards to CmiA's competitiveness due to its higher costs, therefore confirmed to certain extent the similar market treatment to CmiA and other competing labels. Furthermore, various labels are not in direct competition with each other at mills touch-point. Mills and other supply chain stakeholders may subscribe to multiple eco-labelling schemes depending on the actual clients ordering the current production run.

the vertical price differences (premium) with the horizontal quantity output, the total amount of premiums obtained can be calculated (as denoted by the shaded rectangle in Figure A1).



MC – marginal cost
AC – average cost
MR – marginal revenue
AR – average revenue
P_S – short-run price
Q_S – short-run quantity

When supplier's MR equals MR (optimised production level), supplier's short-run price (Ps) is higher than the short-run cost (ACs), resulting in surplus premiums (shaded area).

Figure A1. Short-run equilibrium of the firm under monopolistic competition

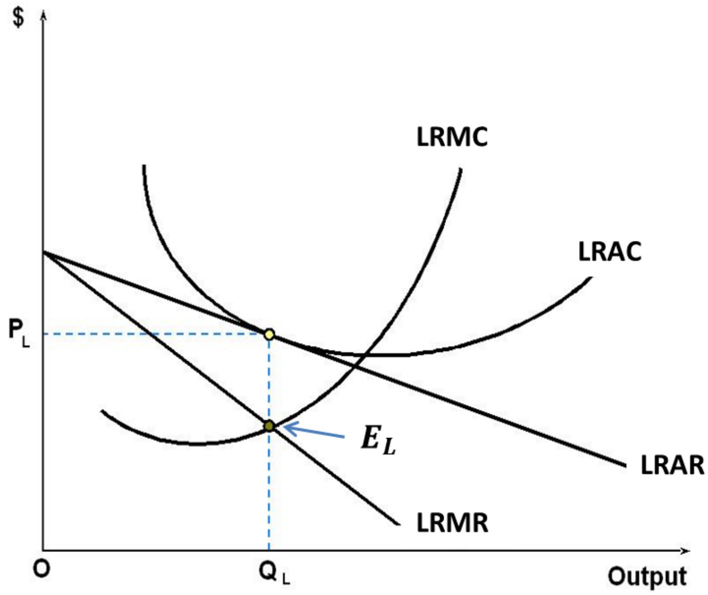
Downstream buyers have the choice to blend different types of cotton and therefore are able to assign BCI/myBMP labels to some fibres instead of others. Because it is reasonable to assume that customers will satisfy their BCI/myBMP quota by committing to the lowest cost cotton as possible, the more expensive Australian myBMP fibre will be subject to unfavourable supply and demand forces (higher cost curves and lower revenue curves), leading to lower premium potentials.

Long-run equilibrium

Due to the existence of above-market premiums on eco-labelling, more suppliers are expected to enter the market who are capable of supplying equivalently labelled cotton products. Apart from suppliers' economic incentive to capture premiums, continuous support from corporates, NGOs and governments (e.g. under BCI or CmiA) will also result in an expansion of supply[24]. Because more eco-labelled cotton become available, the market will exhibit a less price tolerance as denoted by the more flattening demand curves (MR_L and AR_L in Figure A2). In other words, for each additional unit product supplied, the market returns a smaller amount of revenue when compared to Figure A1).

[24] The expansion rate for BCI supply base is expected by the organisers to be 100% p.a. Less advanced growers may also achieve significant efficiency gains and cost reduction by adopting BCI practices which may provide additional motivation to become BCI accredited farmers.

Again, the optimal output is located when suppliers' incremental cost (LRMC) equals to their incremental revenue (LRMR). Point E_L therefore represents the long-run equilibrium position where rational suppliers are expected to stablise. However, at the new long-run quantity Q_L, suppliers' real cost (LRAC) also touches real revenue (LRAR) resulting in zero price premiums. That is, more supplies of the previously non-substitutable products have saturated the market and all previously observable price premiums on cotton eco-labels have fully dissipated. Up to this point, cotton sustainability credentials are fully commoditised and are widely available as an entry-level requirement for legitimate cotton trade[25].



LRMC – long run marginal cost
LRAC – long run average cost
LRMR – long run marginal revenue
LRAR – long run average revenue
P_L – long run price
Q_L – long run quantity

In the long run, the demand curve is expected to flatten and shift downwards (buyers become less price tolerant), resulting in the price level under which the supplier no longer makes surplus.

Figure A2. Long-run equilibrium of the firm under monopolistic competition

Implications to a differentiation marketing strategy for myBMP label

Australian grown myBMP cotton may not have market advantage in leveraging cotton sustainability related premiums than cheaper counterparts. For example, more expensive Australian fibre may be less competitive in the sustainably labelled cotton market, when customers can satisfy their quota by using fibre from regions such as Brazil if it is equivalently certified. Such position is primarily driven by inherent cost disadvantage of Australian cotton industry, and the downstream market's indifferent price treatment to cotton sustainability credentials. Therefore, the current market structure can be seen as posing considerable challenges for the Australian industry's product differentiation strategy aimed at leverage downstream premiums using cotton's myBMP labels.

[25] This is consistent with the mission statement of various NGO and cotton certification schemes.

Appendix 2 Some preliminary evidence on downstream stakeholder perspectives

Supply Chain Stakeholder	On the Value of BCI/myBMP Scheme	On the BCI/myBMP Premiums	On Future Market Outlook	On Cotton Sustainability
Official BCI Organiser	- Growers benefit - Society benefits - Businesses do not benefit	This is a problem driven by limited supply and market opportunism. BCI is a non-commercial farming program.	Premiums will be ultimately eliminated as supply base expands.	- Mission
Brand Retailer*	- Corporate social responsibility and license to operate	Premiums on BCI cotton are illegitimate. The right to BCI product has already been obtained via membership fees, which are used to support farmers.	Brand retailers need to stand firm against paying BCI related premiums.	- Stakeholder requirement - Business Commitment
Mill	- Order qualifier	Increased operating costs to be recovered from supply chain transactions.	- Declining margins and fewer downstream orders	- Client requirement
Chinese Cotton Trader	- Specialised manufacturing material - Cotton differentiator	Current premiums are likely to be initiated by international merchants, and are so far tolerated by downstream clients.	- sluggish economy means clients are less likely to tolerate higher premiums - on the other hand specialised material is becoming more important for survival	- The concept is inconsistent with practice in supply chains
Integrated Cotton Firm	- Building business relationship with brand retailers - Charitable program benefitting growing communities	Premiums are prohibited internally and are not charged to brand retailers. The BCI related costs are negligible when compared to production costs.	The internal BCI supply chain will remain self-sufficient in producing and processing required volumes.	- Client requirement
Post-mill processers*	- Order qualifier	Increased operating costs to be recovered from supply chain transactions.	- Declining margins and fewer downstream orders	- Client requirement

Note: stakeholder perspectives marked with (*) are described by their adjacent supply chain partners.

Appendix 3 Some more successful premium priced sustainable cotton cases [26]

Case	Background	Supply Chain Stakeholders
1. OTTO's organic cotton clothing chain	The large German mail-order company entered the environmental high-fashion market in 1990s. The structure of its cotton supply chain was changed to facilitate better coordination. OTTO is also the main driver behind the current Cotton made in Africa (CmiA).	-small cotton farmers -ginners -spinners -weavers/fabricators -dye house and finisher -clothing producer -large retailer (*focal firm*)
2. Remei's bioRe organic cotton chain	The Swiss yarn retailer entered organic cotton business in 1990s and is still operating today. Instead of following a niche strategy, the company focused on structural changes in its cotton supply chain focusing on long-term partnershipping. The company rapidly expanded and is still operating today as an active player in the environmental cotton business.	-small cotton farmers -local traders -international traders -spinners -yarn agent -yarn retailer (*focal firm*) -weavers/knitters -fabricators -designers and manufacturers -retailers -end consumers
3. Verner Frang's organic cotton	The Swedish yarn trader entered organic cotton business in 1990s following a differentiation strategy. The company faced two specific challenges: 1. There were no producers at the company's supply base; 2. The company	-small cotton farmers -ginners -spinners -small yarn trader (*focal firm*) -weavers/knitters -fabricators -dye houses -clothing manufacturers

[26] The case studies are extracted from previous literature (Goldbach, Seuring & Back 2003; Kogg 2003; Meyer & Hohmann 2000).

	was a power-less small player in both production base and downstream market. VF has merged in 2007 and the new company still operates in the organic cotton market.	

Appendix 4 Gap analysis of myBMP vs. other cotton supply chain

		Australian myBMP Supply Chain	Premium Eco-labelled Chains	Gaps and Future Implications
Offers at Different Cotton Value Dimensions	*Physical Fibre Quality*	There are no differences in fibre quality, nor were there any changes to how cotton is physically processed throughout the supply chain. • ***effect: no value-added***	Survey evidence indicated that customers perceived organic fibre was associated with physically 'smoother' haptic feedback (touch). This perception was further consolidated by the continuous marketing efforts in retail channels. • ***effect: some value-added***	From a marketing perspective, myBMP is likely to remain a pure intangible attribute without linkages to cotton's physical states or how it is transformed in downstream supply chains. • ***implication:*** myBMP credential will be commoditised and bundled with various cotton as cotton buyers see fit
	Demand Fulfillment & Customer Access	When Australian grown myBMP becomes BCI-equivalent, it offers an additional means to satisfy cotton buyer's own downstream orders specifying certain BCI cotton use. • ***effect: some value-added***	End consumers' demand for more organic cotton products was clearly perceived by focal firms, but initially there was initially limited supply to meet such demand. • ***effect: value-added***	The independent myBMP program has very limited presence in the overseas markets. The real demand for myBMP does not occur until the actual order is placed further downstream. • ***implication***: future demand for myBMP will be driven by BCI retailers
	Product Selection & Options	The specifications and volumes of downstream BCI orders do vary, and it is important that customers maintain the choices to bundle BCI labels with different fibre depending on the market conditions; myBMP is seen as the Australian grown BCI bundled with more premium cotton fibre. • ***effect: some value-added***	End customers did not only value responsible fibre materials, but also exhibited other complex buyer preferences. The organic products were not always positioned at high-end premium markets, but were marketed through complex distribution networks aimed at the mass markets. • ***effect: value-added***	myBMP is inherently bundled with more expensive Australian cotton fibre, whereas equivalent BCI accredited cotton is becoming more available from cheaper cotton sources. • ***implication:*** myBMP may have lower buyer preference especially during gloomy economic conditions

	Price & Brand	The observed premium is a compromise between conflicting supply chain objectives; official statements from downstream stakeholders have consistently been against premiums on the BCI (or myBMP) brand. • ***effect: negative value-added***	Organic cotton fibre was established as a premium brand for which downstream customers were willing to pay significantly higher than the average market price. The price was still competitive due to more radical supply chain cost reductions. • ***effect: value-added***	Similar to other customer-driven schemes, BCI/myBMP is officially communicated as a non-commercial, farming program. Supply chain customers may tolerate some premiums but are intrinsically unwilling to do so. • ***implication***: higher premium on myBMP is unlikely to be sustained
	Value-added Services	The myBMP/BCI label is a relevant cotton attribute for some buyers in some occasions, but there is no change to the way downstream customers are serviced by cotton merchants. Growers' adaptation to myBMP/BCI farming practices is perceived to have already yielded on-farm benefits, not relevant to downstream cotton buyers. • ***effect: no value-added***	The focal firms assumed critical responsibilities during the chain's early development stages and provided many value-added services such as training, guaranteed premium contracting and marketing, benefiting all involved supply chain actors and ultimately the end consumers. • ***effect: value-added***	The good traceability of Australian myBMP cotton may be a potential advantage but traceability of BCI in general has not yet become a major issue (as compared to issues such as food safety triggered by certain supply chain scandals). • ***implication:*** it remains unclear what new services can be offered and valued by myBMP customers
	Relationships & Experiences	Apart from within the integrated cotton firms, most BCI/myBMP cotton labels have been transacted via spot markets downstream. In the current slowed-down economies, cotton buyers tend to be cautious and are likely to remain arm's length with the more expensive Australian cotton. • ***effect: no value-added***	Despite varied initial assumptions, all focal firms ended up adopting a relationship-focused supply chain strategy featuring more stable and longer-term partnerships with upstream and downstream actors. The chains became more efficient as actors gained trust and expertise over time. • ***effect: value-added***	Integrated cotton firms (both Australian and overseas) experienced relatively less problems in operating the myBMP/BCI supply chains. The majority of the cotton supply chain exhibits relatively short-term opportunistic orientation not suitable for nurturing on-going customer relationships or experiences. • ***implication:*** For independent actors, myBMP credential may not offer client relationship values or returns
Value Proposition – overall		Limited customer value has been added. On the one hand, myBMP/BCI labelling is part of customers' own	Value was added across different value dimensions. The organic cotton products were offered to end	The myBMP label is currently perceived as a substitute to the customer-driven BCI label, which are increasingly

	client requirements. On the other hand, the downstream customers are increasingly unwilling to tolerate premiums associated with myBMP/BCI labels, making the more expensive Australian myBMP less competitive in gloomy economies. • ***Overall effect: weak and conflicted downstream value proposition***	consumers in the right forms with acceptable cost and benefit trade-offs. The value proposition was relatively consistent throughout the supply chain due to long-term firm relationships and effective cost reduction measures. • ***Overall effect: clear and consistent downstream value proposition***	available from cheaper cotton sources and in open markets. Similar level of premiums is now tolerated for myBMP/BCI labels but this is due to compromise rather than true value proposition to the supply chain customers. • ***Overall implication***: the myBMP is not offering a strong downstream value proposition that may justify a differentiation marketing strategy.
Resources and Competences	• Most resources and competences essential for operating myBMP supply chains are on-farm. The conversion to myBMP or BCI-equivalent farms requires significant investments by farms financially as well as in time and effort. So far these were self-funded by growers; • Post-farm-gate, Australian cotton has relatively good traceability if required. Intermediary firms can achieve this with relatively less further investments; • Further downstream the overseas clients source and manage responsibly labelled cotton with insignificant administrative costs, although some loss of efficiency may occur due to smaller batch and segregation of materials, there are no substantial investments into	• The case supply chains at their initial stages lacked necessary resources and competences to operationalise the new premium-responsible cotton; • Organic cotton products were not readily available from the farms, nor could it be efficiently processed in post-farm-gate supply chains without incurring extra costs; • The focal companies recognised from an early stage that more resources and competences were needed, so they had proactively implemented and funded these across the supply chain touch-points; • Under the finance and coordination by the focal firms, the chains had over time acquired specific production technologies and knowledge unique from the	• The cotton supply chains in general had been lacking necessary resources or competences to grow, process and market a new premium-responsible cotton product line; • While the Australian cotton supply chain has stabilised its cotton flows and throughput by adopting relatively advanced forward contracting mechanism (which itself can be seen as an industry resource), it has not yet been connected to Australian grower's superior environmental performances; • Although the case supply chains showcased their success in their more radical transformation into more capable premium cotton chains, such transformation was chain-wide and costly, which had to be externally funded via some channels; • The crucial success factor was that

	different production techniques; • Although NGOs such as the BCI organisation have pooled resources from across supply chain actors including end retailers, these are primarily for training and supporting less developed cotton farms for non-commercial, non-premium purposes. • ***Effect: Converting to myBMP is costly to growers, and the farms' superior environmental credentials are not being tapped into by the markets.***	traditional cotton supply chains, allowing the new supply of premium cotton products to flow through to the end market efficiently; • The continuous investments into constructing the case supply chains were possible because the focal companies perceived adequate market signals at initial stages, and were able to obtain premium prices in the end markets substantially higher than traditional cotton. • ***Effect: Being ultimately funded by the end markets demand for premium-organic products, the whole chain had undergone costly transformation under the coordination of focal firms.***	some focal firms had perceived adequate downstream market signals and were indeed able to obtain substantially higher selling prices to fund their investments in supply chains. • ***Implication: The conversion into sustainable cotton supply chain requires continuous investments and commitments for change at all touch-points, but these are unlikely to be financed by the downstream markets in the foreseeable future.***
Supply Chain Structure	• The supply chain structure is typical for the agricultural commodity sectors – highly fragmented growing sector with many independent farms; arm's length transactions with more concentrated processing sector; and a short-term opportunistic mentality towards supply chain relationships; • The widely used forward contracting mechanism has stabilised and hedged the cotton supply chains, but this mechanism is yet to incorporate cotton environmental credentials in	• The initial state of the case cotton supply chains are not substantially different from the typical arrangements described on the left; • The focal firms were either intermediary trading companies or retailers who had access to downstream marketing channels; • Regardless of their relative power positions within the chain, the focal firms adopted a relationship-centric approach and had established long-term strategic partnerships with comparable supply chain	• On the supply side, the myBMP program has been driven by industry bodies without the leadership from actual supply chain stakeholders who source, construct and manage cotton related material, information and finance flows; • On the demand side, the overseas cotton buyers and their downstream processing and manufacturing clients remain arm's length and will be operating as per client requirements; • End retailers and NGO organisers are openly against BCI/myBMP premiums

	the domestic cotton market; • Downstream buyers of responsible cotton labels tend to use short-term market transactions through consignment or cargo deals without long-term commitment to the inherently more expensive myBMP; • As indicated in Figure 3 (page 12), short-term opportunistic negotiations prevail in the current myBMP/BCI supply chains while the information and finance flows are not integrated, nor channeled back to the cotton farms; • ***Effect: the myBMP cotton supply chain is governed by the 'open-market' mechanism under which most family growers rely on their transactions with merchants /ginners post-farm-gate, while myBMP is not yet part of the deal.***	counterparts including growers and all processing stages; • The size of the operations varied from targeting niche or mass market, but the focal firms were able to continuously earn substantially higher selling prices and share with all supply chain participants through explicit contracting arrangement; • As indicated in Figure 4 (page 16), short-term negotiations were replaced by the focal firms' central coordination and guaranteed stable and premium contracts with chosen counterparts, resulted in a shorter, stable and more integrated structure. • ***Effect: The case supply chains (especially at their earlier stages) were governed by the focal firms who effectively constructed a new overarching supply chain structure***	and the 'problems' are seen as solvable by expanding the scale of the BCI coverage in the producing sector without attempting to alter or govern the supply chain structures; • Cotton growers are seen as already beneficiaries of adopting better farming practices, no supply chain stakeholders expressed clear intention or plans to finance growers for becoming myBMP/BCI accredited. • ***Implications: No focal firms have been identified to orchestrate a premium-responsible cotton supply chain for myBMP***

Australian Cotton: Accounting for value chain sustainability and competitive advantage

Third Year Report: Objective 2

Integrated Sustainable Management System

Environmental Performance Measurement Systems for

Cotton Growers

October 2016

This final report has been submitted to the Cotton Research and Development Corporation (CRDC) as part of the project: Australian Cotton: Accounting for value chain sustainability and competitive advantage (CRDC reference code: UTS1201). The project is jointly funded with UTS Business School.

Please note, feedback from the CRDC and other key stakeholders will be incorporated into an updated version if the report is subject to general release.

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Table of Contents

Executive Summary

Given the broader pressures on cotton farms to be environmentally and economically sustainable, the efficient and effective use of resources and the attempt to reduce resource abstractions from the natural environment down to zero or some irreducible minimum is becoming increasingly important. In this project we identified two key areas that are central to the sustainability of cotton farms - water and energy.

The approach taken in this research was to design an environmental performance measurement system (EPMS) to enable farmers to make decisions about resource use and decide what practices are likely to improve environmental and economic sustainability. For the EPMS to have utility, measures need to be *valid* (measures actually capture what they are supposed to reflect) and it needs to vertically link high level organisational outcomes with operational work and decisions.

A well-designed EPMS enables meaningful work to be undertaken on setting targets for performance and process improvement. We have set a five-stage target model that starts with current practice (Stage 1) and ends with the ultimate in performance, which is the theoretical ideal (Stage 5). This is the best that can be delivered given the constraints of nature and science.

We then tested the developed model using simulation modeling. We used SIRMOD to determine water infiltration and runoff characteristics and DSSAT to cycle through 100 years of weather data and crop production. We then used this and other economic data to input into the developed EPMS. We modeled furrow irrigation (current practice Stage 1), then the improvement in current irrigation practice (Stage 2), and tested for the differences between these. The simulation provided evidence for an improvement in overall crop water management sustainability; with results indicating a 59% increase in profit to water cost ratio, a 27% reduction in water use, and a 13.5% increase in profit.

This research sets out the architecture of an EPMS focusing on water and a subset of energy. It can be used as a strategic guide quantifying the effect of proposed changes in practice or investment in new technology on the overall environmental and economic sustainability of the farm. The research can inform major investment decisions, and potentially demonstrate the profitable nature of environmentally sustainable technologies.

Report Objective, Milestone and Performance Indicator

This report is the final report for:

Objective 2: To develop the design for an integrated management system for Australian cotton growers which supplements myBMP to provide better sustainability management and greater product value post farm gate.

Milestone 2.3: Complete design of integrated management systems that supplement myBMP to enable sustainable management and decision making at the farm level to gain more value post farm gate in two key areas of sustainability.

Performance Indicator 2.3: Final version of enhanced information systems design using accounting principles for myBMP.

Theses Contributing to this Report

Research undertaken for these doctoral or Honours theses has been included in this report:

1. Pham, H., 2016, Design of Environmental Performance Measurement Systems for Agriculture

This thesis will be made available to CRDC.

1. Developing an EPMS

1.1 Introduction

"*Any sufficiently advanced technology is indistinguishable from Nature*" (Karl Schroeder 2015)

The concept of sustainability is inextricably linked with the reality of human action. Sustainability is generally thought of in terms of preventing irretrievable loss of the planet's natural resources, through destruction, dissipation or contamination, as a result of human activity. This is very much in evidence in the injunction of the Brundtland Commission[1] (The Brundtland Commission 1987). The concept of human needs is at the heart of the Brundtland definition.

But human activity is inevitable. Deutsch (2011) characterises humans as the only species on this planet capable of the open-ended generation of knowledge and its deployment to modify their environment. Inevitably, this will use natural resources and thus the issue of sustainability is engaged. We must agree that the elimination of human activity is not an option, hence there is an incentive to ensure that what activity occurs, does so with most reliance on renewable resources and minimal impact on non-renewable natural resources.

The nature of human activity is therefore crucial to any attempt to achieve sustainability. A moment's consideration will lead to the recognition that the activities that are most likely to cause sustainability problems are those associated with work and are the result of decisions and actions taken in pursuit of work. This is true whether the agency is a government, corporation or individual worker. We might control work by regulation, as has been the case in

[1] The Brundtland Commission developed and published a broad concept of sustainable development, defined as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (The Brundtland Commission 1987, p. 1).

the international efforts to reduce CFCs, remove leaded petrol and ban methyl bromide, to name just a few instances. However, the range of activities engaged in work is almost limitless and regulation would be impractical in most circumstances.

More practically, the approach we adopt is based on the premise that human agents will aim for sustainability if that is at least aligned with the purposes of their work or, better, augments it. The work in which we are interested is, in this case, the cultivation of cotton. Cotton farms exist at the intersection of ownership of suitable land, access, if required, to supplementary water, an unsatisfied demand for cotton and a skill set that permits satisfactory growth of the crop. Many different patterns of intersection of these parameters can be conceived. Some will even be profitable: our concern is with these farms.

Several decades ago, profitability may have been the significant determinant of the success of a farm. However, social concerns that have emerged particularly since the 1960’s now place an implied value on another attribute of the farm: its sustainability, particularly its environmental sustainability.

1.2 Value of sustainability to Australian Cotton Farming

Work completed in other parts of this project reveals that, contrary to the expectations with which we began the project, given the current state of cotton markets sustainability *per se* is not an attribute that is likely to translate into permanent and economically significant price premiums for Australian growers. Such premiums as there are, tend to dissipate with time. BCI does not command a premium, but intends that the market will determine if BCI cotton commands a premium. As it achieves its goal of becoming a mainstream commodity, it is unlikely that price premiums will be maintained.

If sustainable cotton production does not have a guaranteed price advantage, why should a grower pursue sustainable production? There are three main reasons.

a. Social licence to operate[2]. This is a familiar term in the mining industry (Lacey, Parsons & Moffat 2012) and "generally refers to a local community's acceptance or approval of a company's project or ongoing presence in an area" (O'Connell 2016). It is not legislated, but is an articulated view of the community that the benefits from the operation outweigh the costs. For cotton, the major benefit, particularly to the local community, is that it is a conduit of affluence into the community, which is expressed in continuation of local support industries, enterprises and continuing employment. For the larger community, the cost is a level of exploitation of natural resources. Public discussion about the use of pesticides in cotton and the extraction of water for irrigation are examples of this articulation process. Demonstrated sustainable performance in cotton farming that is based on reliable and objective indicators will be an important element in such discussions, providing an important justification for continuing to meet society's needs for this fibre through farming.

b. Enhanced profitability provides greater opportunity for weathering the vagaries of climate and markets to which farming is subject, thus ensuring that the business can endure. This, in turn, provides an on-going basis for the farm to continue to exercise good environmental stewardship of its country. As well, simply by being sustainable, the farm must use natural resources more efficiently, thereby increasing its chances for

[2] A farmer's social licence to operate is determined based on the legitimate boundaries between right to exploit and obligations to conserve natural resources (Williams & Martin 2011).

continued operation.[3] Because of the sustaining effect of profitable farm businesses on their communities, an enduring farm will continue to support and stabilise that community.

c. Additionally, another section of this project (Jin, Brown, Brown & Agarwal 2015) showed that, in the future, re-configured value chains may be better able to accommodate sustainability of production as another valuable quality characteristic.

In all three cases above, sustainability needs to be quantitatively and defensibly described so that, whatever the context, the credentials of any cotton farm can be accessed and deployed. For instance, the second standard in BCI states "Better Cotton is produced by farmers who use water efficiently and care for the availability of water". The criteria for sustainable use of water that we describe must provide, *inter alia*, adequate defence of the farm meeting this standard.

Our task is to demonstrate how to design a system for any cotton farm that properly describes and leads to improvements in its sustainability, considered from the duality of environmental and economic aspects. It is immediately clear that "sustainability of the farm" is simply too broad and imprecise a term to be useful. Instead, we need to identify the suite of natural resources used or impacted by the farming operation and ask, for each, if the current operations achieve the desired sustainability. Our brief was to consider sustainability in this light with respect to energy[4] and water.

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[3] We contrast this with mining; exemplified by the Mary Kathleen mine, which closed when the orebody worked out, leaving a huge hole in the ground, spoil dumps and the loss of a regional community.
[4] While the modelling may be extended to include other sources of energy such as Nitrogen (e.g. Patzek 2004), to keep the analysis tractable we have restricted the modelling to direct energy and specifically focused on diesel consumed in irrigation operations. Earlier reports provide further insight into how the modelling could be extended (e.g. Brown, Brown, Pham & Sutton 2013).

A key challenge in articulating the sustainability of a given resource is the trade off with other resources which result from necessary changes in technology. For example, it may be possible to increase the water efficiency (more sustainable) but by using an energy intensive process requiring more diesel (less sustainable). While we have considered both energy and water in this report, more work is needed on identifying and modeling these tradeoffs as they relate to cotton production.

2. Need for an EPMS

The context of sustainability implies a dynamic system in which changes in social permissions and accessible technology will drive continuous redefinition of sustainable performance. Particularly at the level of individual farms, dependence on random choice, intuition or irrelevant factors is unlikely to lead to a desirable result. An EPMS, a subset of performance measurement systems (PMS) which are traditionally defined as the systems that provide financial and non-financial information intended to be useful for managerial decision making and control to ensure the attainment of organisational objectives (Franco-Santos et al. 2007; Otley 1999), provides a feedback loop that allows the farm manager and operator to decide what practices are likely to improve sustainability and, *post hoc*, whether they have worked. We have previously described the overall operation of an EPMS (second year report); here we deal with the related issue of how to *develop* the EPMS in the first place.

There are four phases in EPMS development: design, implementation, use, and evaluation (Artz, Homburg & Rajab 2012; Bourne et al. 2000; Ferreira & Otley 2009; Neely et al. 2000; Neely et al. 1997), with the evaluation phase addressing whether the EPMS is accurately aligned with the current organisational strategy. The purpose of the EPMS is to capture quantitative information about organisational performance, which can then be used by managers and operators to guide farming operations and processes so that key strategic goals can be achieved (here we have environmental and economic sustainability as the focus).

From this position, several key aspects of the design of the EPMS can be inferred.

2.1 System definition

Farming is a complex system with many interlocked processes and states (a state is, in essence, a description, for example, depth of water in a dam). It follows that measuring performance of the system must be based on measurements made at key points in the system. Decisions about where to make these measurements must, logically, rest on a sound and complete scientific description of the system. We describe later how we identified and codified such a description for our proposed cotton EPMS. The sequence of processes and states defines a critical path for resource utilisation in the system[5].

2.2 Organisational linkage

It is easy to see in a large, vertically-linked organization, that directors leading the company will most probably have differing needs for sustainability performance from staff at the operational level, whose immediate focus is on the current task and its operating environment. The information required at the director's level will underpin strategy development for the organization, as well as describing how well the organization's performance is aligned with existing strategy. For these purposes, high-level summary parameters that describe the sustainability performance of the organization as a whole may be most useful. However, at the operational level, the information derived from the EPMS must assist staff make decisions at the level of day-to-day operations. A more extensive suite of fine-grained parameters will be needed here. Additionally, both sets of parameters, fine-grained and summary, must be functionally linked so that all staff have confidence that their efforts are encompassed in a single system.

[5] We use the term "critical path" as this sequence is analogous to the critical path defined by resource assignment in project management.

The above paragraph can be easily visualized in a large organization with a hierarchical staffing structure. We believe that it also applies to smaller organizations such as family farms, where the same person acts both as director and field hand. In this case, the manager may assume different *roles* at different times (strategic planner on infrequent occasions, field hand more regularly) and will require the appropriate information from different levels of the information hierarchy within the EPMS at those times. Thus, a common EPMS architecture should suit both large and small organizations.

2.3 Validity

The need for validity in measurement seems both obvious and intuitive, but it is the element of EPMS design that the literature suggests is most problematic. A broad definition is given by Ittner and Larcker (2003), where validity is defined as *"the extent to which a metric succeeds in capturing what it is supposed to capture"*. More formally, we offer the following definition" (Ittner & Larcker 2003, p. 92).

1. Validity of a measurement encompasses three complementary elements. To manage a process or state within an organization, we identify an attribute which unambiguously describes the desired performance of that process or state, e.g. a rate or a conversion efficiency of a process, a yield.

    1.1. The measure of that attribute should be directly related to and traceable to the performance, e.g. the rate is measured as the flux of a key component in the process per unit time.

    1.2. The measure must be capable of being performed, that is, there needs to be a method by which the measurement can be made.

1.3. The measure must be accurate to within acceptable limits and preferably we know the acceptable range within which the results should lie.

2. As noted earlier, an organization consists of many interlocked processes and states, so a valid EPMS must depend on many valid measures, BUT, as all measures in an EPMS are, by definition, on the critical path, all must be valid for the EPMS to itself be valid. Further, it is obvious that summary measures derive their validity from the validity of the underlying measures of specific processes and states.

2.4 Utility

It goes without saying that an effective EPMS is, above all else, useful. This means that, not only should its information be obtainable and accurate, which we have discussed, but it should provide clear guidance to managers regarding operational decisions, while simultaneously providing evidence that sustainability has, in fact, been achieved.

Against what background is this latter judgment made? We alluded to this in the second year report and two elements of that, bear attention here.

We noted earlier that, for each measure, we should know the range within which the results should lie. Implicit in this is the idea of targets. Within each range and typically at one extreme, there will be a value which represents the optimal case, at which that process or state is making its maximum contribution to the overall sustainability of the farm. We will point these values out in later sections when the EPMS is described in more detail.

We also noted in the second year report that staged targets might be effective. Our argument here has evolved and runs as follows.

Traditionally, when profitability was perhaps the most significant determinant of a farm's success, sustainability may not have been a prominent goal of the farming operations. In this case, the sustainability of resource use by the farm may be at some departure from the ideal, but by how much? What effort and investment might be required to improve this situation? We suggest an evolutionary approach to achieving sustainability, with five target stages.

Stage 1. **Current practices**. The performance targets are based on current farming practices to provide a baseline assessment of sustainability of the farm.

Stage 2. **Current technology**. The performance targets are estimated assuming the technologies used on the farm are deployed optimally, e.g. furrow irrigation practices have been optimised for the soil types, slopes, field layouts etc. In essence, this demonstrates, compared with Stage 1, what improvements in sustainability can be achieved with minimal investment and disruption to existing farm practice.

Stage 3. **Best available technology**. The performance targets are estimated assuming the technologies used on the farm are the best currently commercially available. For instance, investment might allow the replacement of furrow irrigation with subsurface drip irrigation. The EPMS should also assume changes in related farm practices, such as land preparation, that the new technology implies.

Stage 4. **Best conceivable technology**. The performance targets are estimated assuming the availability of scientifically plausible technologies that are not yet commercially available, for example, demand-driven subsurface irrigation. The outcomes here may be of greater importance to organizations such as CRDC than to farmers, as it will illuminate the industry benefit of sponsoring development of new technologies.

Stage 5. **Theoretical ideal**. The performance targets are estimated assuming all processes operate at their theoretical ideal. This stage provides an opportunity to impose real-world limits on community expectations of sustainability performance by the farm. For instance, ideally, deep drainage should be zero from a purely water perspective. However, this might not be achievable or desirable in practice. Even with perfectly managed irrigation, deep drainage will unavoidably occur after significant rainfall events. In fact, the history of the Australian landscape appears to have been one of limited deep drainage leaching wind-blown salt accumulation in the topsoil. The theoretical ideal would also take into account the sustainability of all operations under consideration, including energy and waste.

The stages, which may differ appropriately as the focus moves among different resources, are intended to be aligned with major investment and re-tooling decisions. Two sorts of information, in broad terms emerge for farmers and their advisers:

a. What is the maximum sustainability that can be achieved if the farm retains its current technology mix?

b. With additional accounting input, can the EPMS demonstrate that a shift to a more sustainable technology be justified on both environmental and economic grounds? Hopefully, we can demonstrate that sustainability is profitable.

In the development of the EPMS, we will use a comparison of Stage 1 with Stage 2 (See section 5 below ‘Applying the EPMS: a simulated case study’).

3. The Architecture of an EPMS for Cotton Farming

We have interpreted our brief to require the development of a prototype architecture for an EPMS applicable to cotton farming. Because sustainability is about competent use of natural resources, it can be assessed with respect to each natural resource involved in the farming of cotton. On this basis, we have, as our primary focus, done this for crop water management in cotton farming. If the architecture is valid, not only must it meet all the criteria discussed earlier, but it should, in broad structure, also be applicable to other resources used in cotton farming. For this purpose, we have also demonstrated its applicability to a major component of direct energy use in cotton farming, which is the diesel used in crop water management.

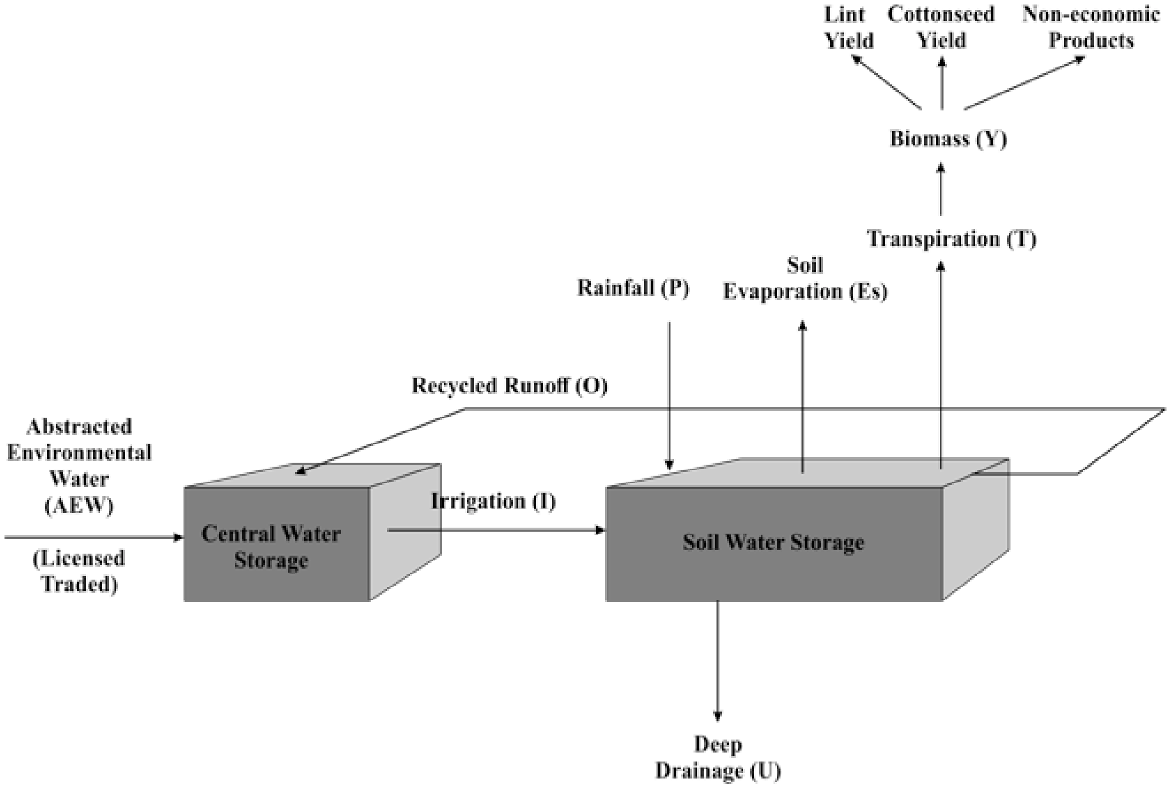
Following the discussion of validity earlier, for these two resources, we identify the critical path of the flux of water and associated energy in cotton farming, based on a sound theoretical description of the processes involved, from which key measures and targets are identified.

3.1 Theoretical Description of Water Use in Cotton farming.

For this stage, a simplified description illustrates the key flow paths for the natural resource through the farming system (Figure 3.1).

This figure depicts the simplest system of a farm with a single irrigated field. Crop water is supplied (CWS) either as rain (P), which is presumed free or supplementary irrigation (I) from a central farm water storage. Water is lost from the field productively as transpiration from the crop (T) or non-productively as soil evaporation (Es), deep drainage (U) or surface runoff (O). The latter (O) is retained and recycled to the central storage. As needed, the central storage is replenished with water abstracted from the environment, that is, water taken from rivers or bores (AEW). The latter (AEW) is regulated and valued via licensing or trading. Drainage is a potential source of pollution and both soil evaporation and drainage represent loss of paid water.

Figure 3.1: Crop water process model showing the critical path for water in cotton production



Water has another characteristic in this setting. Transpiration is directly related to yield and hence indirectly related to profit. Other environmental attributes (radiation, temperature, humidity, soil, physical, chemical, and biological fertility) will set a potential yield limit and irrigation is added to the cropping system to ensure water is not limiting.

Note that water is, in essence, a renewable resource, but the problem with respect to its sustainable use is that the pools that provide for human access to it, have finite renewal or replenishment rates, so abstraction by all users from these pools at time scales shorter than the replenishment rate must be managed to ensure water stocks in the pools are non-zero. Even then, because the replenishment rate is weather-dependent, drought may necessitate the restriction of abstraction to only the highest priority users, usually water for stock and domestic uses.

An irrigated cotton farm sustainable with respect to water might therefore be defined as one which achieves a yield commensurate with the site potential, but with abstracted water volumes tending to zero or some irreducible minimum. This can be described by the following equation:

Equation 1: Criteria for water sustainability

$$Y = Y_{max}$$
$$CWS = T$$
$$O = 0$$
$$E_s, D \rightarrow 0$$
$$AEW \rightarrow 0$$

3.2 Theoretical Description of Energy Use in Cotton Farming

Water and energy, as attributes for sustainability assessment, differ in at least three fundamental ways.

First, as described above, water is effectively a reagent in the biology of cotton growth. In contrast, direct energy (i.e. diesel) facilitates cotton cultivation but is not otherwise directly consumed by the process. In that sense, it is more analogous to a catalyst than a reagent.

Second, the consumption of water by the crop is strongly weather-dependent, on a broad range of time scales. Thus the management required to ensure water is always non-limiting will be largely weather-driven. In contrast, many of the operations consuming energy are not related at all to prevailing weather conditions and are to that extent, sunk costs. Cultivation of the soil prior to planting might be an example of this. There will be other operations such as operation of lifting pumps to recycle water that depend on the frequency of irrigation, itself weather-dependent. This suggests that the theoretical model on which sustainability assessment is based might be different from that used for water.

Third, water in crop production is pretty much a one-dimensional issue: water is used to maintain cell turgor and hence growth. In contrast, many different forms of energy can be used in a wide range of processes and operations to grow a single crop. This is illustrated in the following table (Table 3.1) taken from Table 2.6 in the First year report.

Table 3.1 Forms of direct energy possible for cotton growing. (Filled boxes mark current or plausible use of that form of energy in an aspect of cultivation)

Energy Categories	Total Direct Energy Input								
	Total Conventional Energy Input				Renewable Energy Input				Human
	Total Liquid Fuel Input		Total Electricity and Gas Input						
	Diesel	Petrol	Electricity	Gas	Solar	Wind	Biofuel	Biological	Human
Operations									
Tilling	■	■	■	■	■	■	■	■	■
Sowing	■	■	■	■	■	■	■		■
Irrigating	■	■	■	■	■	■	■	■	■
Fertilising	■	■	■	■	■	■	■	■	■
Pesticide Spraying	■	■	■	■	■	■	■	■	■
Herbicide Spraying	■	■	■	■	■	■	■		■
Cultivating	■	■	■	■	■	■	■	■	■
Crop Growth								■	
Harvesting	■	■	■	■	■	■	■		■
Post-Harvest	■	■	■	■	■	■	■	■	■
In-Crop Services	■	■	■	■	■	■	■		■
Administrative and Support	■	■	■	■	■	■	■		■

Confronted with this matrix, we recognise that, to a large extent, current energy inputs to cotton cultivation (with the exception of the solar energy used by the plants for photosynthesis) are both strongly dependent on non-renewable fossil fuel feedstocks and contribute to GHG. The benchmark for sustainability in this context was set by Patzek (2004) who observed that the only flows through the system should be derived, reasonably immediately, from renewable sources. In terms of energy, solar energy is the primary source which meets this criterion. Wind, biofuels and biological energy are secondary sources derived from solar energy and thus are considered renewable. We can therefore summarise the sustainability goal for energy as:

Equation 2: Criterion for energy sustainability

$$\sum E_{\text{in, non-renewable}} \rightarrow 0$$

We can define sustainable with respect to energy, as a cotton farm that uses only renewable energy sources for its operations. Analysis of the above table shows several categories of direct energy use:

A. Heavy draft such as those used in cultivation, possibly sowing, harvesting and post-harvest operations.

B. Light draft such as those possibly used for applying chemicals.

C. Transport of personnel and materials about the farm.

D. Non-field crop-dependent operations such as irrigation.

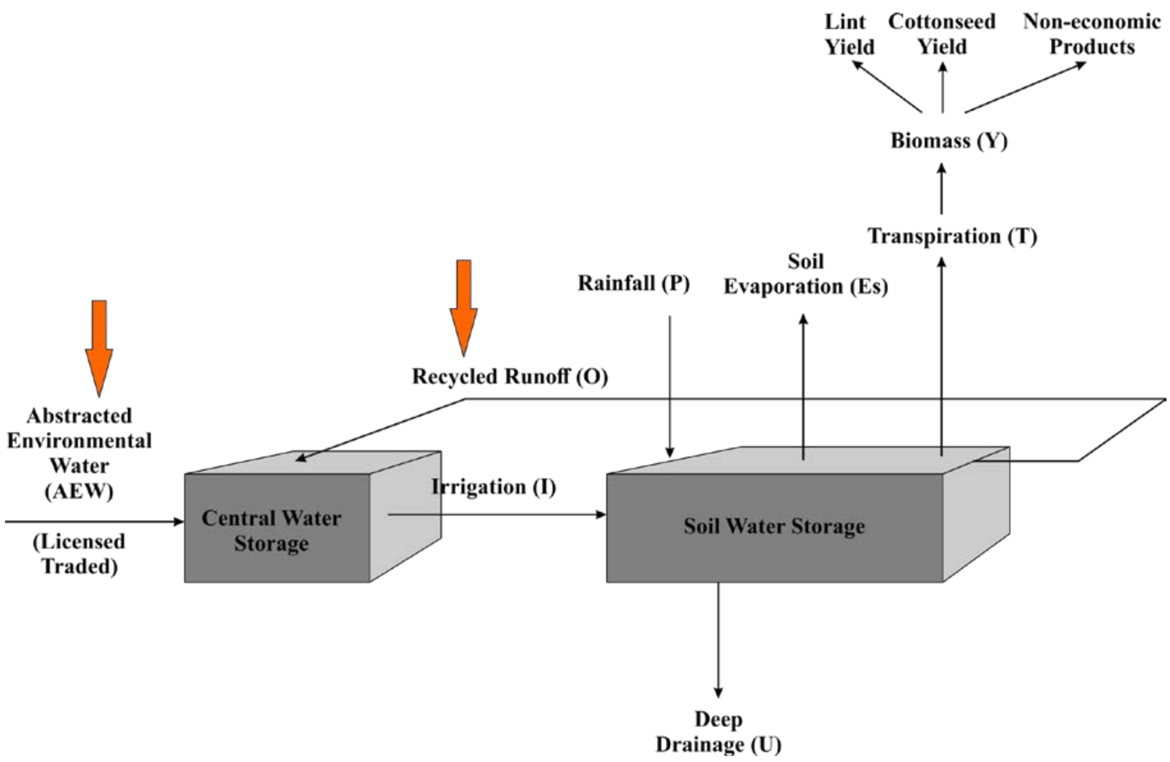
Because the energy use within each category has many common features, it may be logical to approach the issue of overall sustainability by independently attempting to achieve sustainability within each category.

There is, as always, another way of examining energy use in cotton cultivation: the contribution each operation or class of operations makes to total energy expenditure. In traditional cotton farming systems, the irrigation process typically consumes 40-60% of total on-farm energy inputs, followed by the harvest process (20-25%), planting (10-15%) and field operation (10-15 %), while post-harvest and in-crop operations make up less than 10% each. The level of energy consumed by each process is dependent on a range of management decisions such as choice of tillage method in the field preparation process, or between irrigation systems in the irrigation process (Khabbaz 2010). From this sort of analysis, improving sustainability of energy use in crop water management would have a significant impact on overall energy sustainability.

As our interest is focused on sustainable water use, we have chosen to explore issues of energy sustainability within this context and our test of the applicability of the EPMS architecture will be constrained to this. The following diagram (Figure 3.2) indicates (orange arrows) where energy associated with pumping is incurred in crop water management.

The first process that may be involved is the pumping of water from rivers or bores, where such water is not supplied by gravity flow from upslope weirs. There may be a second pumping step in lifting water into the reservoir. Following the path of water into the field and its application, in this instance, by furrow irrigation, the energy for water flow is provided by gravity. Water running off the fields flows, also assisted by gravity, to a collection point in the recycling system where it is elevated into the reservoir. In this analysis, energy associated with water management is restricted to that used in pumping (Chen & Baillie 2009).

Figure 3.2: Direct pumping energy inputs (coloured arrows) into cotton crop process model.



However, reflection reveals that energy has been used in other processes without which the crop water management would fail. Land forming occurs at regular intervals to provide a controlled slope for gravity-assisted water flow. Frequent reforming of beds provides the furrows which apply the water to the field. Because the crop is sensitive to waterlogging, such surface management is essential to ensure rapid draining of runoff after irrigation and rainfall. There are increasing accounts of such land forming also being used in rainfed crops, again to improve in-field crop water management. In the extreme, given the success of cotton cultivation with significantly reduced tillage, a significant fraction of the energy currently accounted for as cultivation in an irrigated cotton crop, must more accurately be considered as part of water management. In addition, energy is expended in channel forming and maintenance, head-bay forming and siphon deployment.

These latter energy expenditures are not captured by the crop water process model as they are temporally separated from irrigation. Instead, activity-based costing, discussed in the first year report (Brown, Sutton, Brown, Agarwal, Pham & Thambar 2012), provides a mechanism for identifying and quantifying such expenditure.[6] This is important, as adoption of different irrigation technology, for instance, subsurface drip irrigation, will probably allow some of these operations to be avoided.

3.3 Financial Engagement with Physical Sustainability

For the farm to be economically sustainable, financial resources need to be deployed efficiently. The crop water management and energy models in earlier sections indicate some expenditure and revenue potentials, but do not financially account for them. For this, we need an extension of our model, as described in the Second Year report. Here we elaborate the implications of this approach.

DuPont, in the 1920s, introduced Return on Investment as a high level summary statistic that provided information on the economic health of an organization[7]. We proposed an analogous parameter, the Profit-Water Cost Ratio (PWCR), as the

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[6] For more detail on the application of activity-based costing to the management of energy, see the teaching case prepared by Pham, Brown & Brown (2013).

[7] DuPont analysis, an analysis technique commonly used by market participants for financial statement analysis, decomposes return on net operating assets into two components: profit margin and asset turnover (Soliman 2008).

summary parameter for assessing sustainability of water use by the farm. The formula for calculating PWCR is given in Appendix 5 of that prior report, but is reproduced here for clarity: PWCR = Operating Profit/Total Water Cost. The water costs are the licence fees paid for access to environmental water, are directly related to volume abstracted and, as noted in Equation set 1, should tend to an irreducible minimum. As such, they reflect the environmental sustainability of water use by the farm. Operating profit has its normal meaning and reflects the economic sustainability of the farm. Taken together, we expect PWCR to increase as the farm becomes more sustainable. Trends in this parameter could be used at a strategic level in the organization.

However, reliance on a single parameter has two problems. First, of itself, it provides no information as to whether an increase has been caused by improvement in profits, a decrease in water abstraction, or both. Second, it provides no useful information at the operational level in the organization, where specific management decisions need to be made. Consequently, we also proposed, again analogously to DuPont, that this parameter be decomposed, level by level, to both reveal more specific and hence operationally-meaningful information and intersect with the fine detail of the water and associated energy process models. The aggregate we have termed WESM - Water and Economic Sustainability Performance Measurement and propose it as the appropriate EPMS for crop water management. A detailed layout is provided in the Appendix.

An equivalent structure was used for assessment of the environmental and economic sustainability performance of direct energy use associated with cotton production. This was developed from the second year report (Brown, Brown, Pham & Sutton 2013), but is, we recognize, incomplete as it does not account for all energy used in growing the crop.

In subsequent sections, we examine the use of WESM and its energy counterpart to analyze the sustainability consequences of transforming a furrow-irrigated cotton farm from Stage 1 to Stage 2. This will provide an opportunity for us to guide the reader through the decomposition analysis, identifying the key parameters and drawing appropriate management decisions from them.

4. Development of Key Metrics

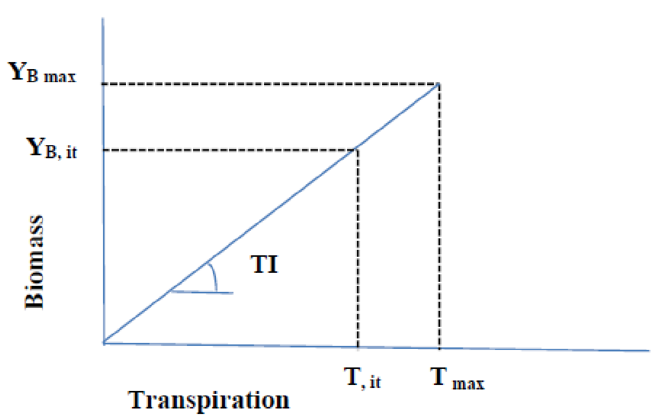
Equations 1 and 2 describe the ideal or limiting case. However, from a management perspective, it is crucial to know not only that sustainability might not have been achieved, but how far from the ideal is the system operating. Equally, the metrics used to demonstrate this should also be easy to relate to management decisions that are meaningful in the real world. We do this now for water and energy, in turn.

4.1 Key Water Sustainability Metrics

4.1.1 Identifying the Metrics

The point of growing cotton is to produce a quantity of fibre, which can be sold at a profit. Thus a key part of the farming system is the process which captures both the actual utilisation of the natural resource and the production of the fibre precursor. This is, for a plant, photosynthesis, where carbon from the atmosphere is assimilated into carbohydrates, the precursor of cellulose and, simultaneously, water is lost through open stomata as transpiration. The two processes can be related as shown below to give the transpiration index (TI) (Figure 4.1).

Figure 4.1: Theoretical relationship between transpiration and biomass



The point (T_{max}, $Y_{B,max}$) represents the best use of the environment in that location and season to produce cotton biomass, assuming neither water nor other determinants of cotton growth such as fertiliser, are limiting. T_{max} is the amount of water productively used by that crop. If less water is available (T_{it}), then yield ($Y_{B,it}$) will be commensurately reduced. TI itself is relatively invariant, being affected mainly by humidity, but T_{max} may vary considerably from year to year, responding to changes in the weather. Similarly, Y_B will vary, but if maximum use is to be made of the environmental resources of the site, Y_B should approach $Y_{B,max}$ each year. This satisfies the first condition of equation set 1.

Because only transpiration is linked to crop growth, any other loss of water from the farming system should be minimised, particularly as at least some of that water will have been abstracted from the environment and will have been paid for at some cost. Ideally, all water supplied should be used only to contribute to transpiration. The absolute amounts will vary year to year due to weather differences, so we introduce the relative metric, water input efficiency (WIE) where:

Equation 3: Water Input Efficiency (WIE)

$$CWS = I + P$$

$$WIE = \frac{T}{CWS}$$

Crop water supply (CWS) is defined as irrigation plus rain falling on the field. If there is likely to be a significant change in the soil moisture storage in the root zone from beginning to end of the crop cycle, then that change may be included: here we assume that there is zero change. Water input efficiency (WIE) describes the proportion of crop water supply that is consumed by transpiration. It has a theoretical maximum of 1, at which the conditions in the second line of equation set 1 are met.

Line 3 of equation 1 is set by legislation and engineering. Farmers are required to prevent water carrying chemicals (pesticides and fertilisers) from entering the environment. Thus recycling schemes to capture water running off the field and return it to the central storage are routine. They serve a second important function: surface flow irrigation, typically furrow irrigation, almost always results in runoff. This can be captured and recycled by the same system, achieving a significant increase in overall system water efficiency.

Given lines 2 and 3 of equation 1, line four follows as a corollary, that is, irrigation management must be such to ensure that as little of the applied water as possible is lost by deep drainage below the root zone or as evaporation from wet soil surfaces.

Line 5 of equation 1 follows if the conditions set in the previous lines are met. In practice, the central water reservoir from which irrigation is drawn will be replenished by recycled water, including “external” water, that is, runoff following rainfall and by water abstracted from the environment (AEW). As an irrigated farming system approaches water sustainability, the volume of water abstracted from the environment will diminish. One can consider the ratio AEW/CWS, which will have a range from zero when no abstracted water is used, to one when only abstracted water is supplied to the field.

The above discussion can be easily adapted to provide a theoretical description of water sustainability in rainfed (dryland) cotton farming. By definition, AEW will be zero and the role of the manager will be to ensure that, as CWS=P, CWS = T. Given that under these circumstances $T<T_{max}$, some change in crop management,

typically sowing density, will need to be made to ensure CWS=T. As a consequence, $Y<Y_{max}$.

So far, we have focused on the logical sequence between water application and biomass generation (Y_B). Biomass is not an economic crop product in this context, so our interest is in the plant's conversion of biomass into lint and possibly seed. The parameter used to describe this is harvest index (HI) and is calculated as:

Equation 4: Harvest Index

$$HI = \frac{Y_L}{Y_B}$$

,where Y_L is the lint yield.

Once lint has been produced and harvested, as raw seed cotton, we need to understand the handling, marketing and processing processes as they relate to the farm. That is, while we have drawn a boundary around the farm to consider the sustainability of use of the natural resource, water, on the farm, we need a boundary that extends beyond the farm sufficiently for the economic consequences of cultivating the crop to be properly accounted for. We have decided to draw this boundary at the point where the farmer consigns title to the lint to a third party. The chain of post-field processes that need to be accounted for is therefore haulage of cotton to the gin, ginning and handling costs.

4.1.2 Quantifying the Water Metrics

From the preceding section, we can tabulate the data required to calculate water sustainability parameters.

Table 4.1: Water metrics

Required data	Type	Data source
Water drawn from the environment (AEW)	Dynamic	Pump records
Rainfall	Dynamic	Meteorological observations
Irrigation	Dynamic	Farm records
Runoff	Dynamic	Farm pump records
Soil evaporation	Dynamic	N/a
Deep drainage	Dynamic	N/a
Transpiration	Dynamic	N/a
Y_B	Dynamic	N/a
T_{max}, $Y_{B,max}$	Dynamic	N/a
Y_L	Dynamic	Farm records
[include here post-farm gate items]	Static per unit	Farm records

Data are described as dynamic if it is likely to vary, typically in response to daily weather. Static data are, for instance, contract prices per bale. Some data may be available from farm records, and might already be collected under myBMP practice, although of variable quality, such as the estimates of irrigated volumes. Other data are not directly measurable in the farm context.

For this reason, we chose to use simulation modelling to provide dynamic data. The model used was the cotton module in DSSAT, for which the input data were soil type and meteorological observations (Jones et al. 2003). The irrigation module was edited to allow a realistic simulation of the furrow irrigation process across a field, including the inherent variability in water supply along a furrow. By using 100 years' of weather data, we were able to simulate yield and the necessary data across the full range of weather experienced at any given site.

The use of a long run of weather data is important in two ways. First, it gives a clear idea of the robustness of key parameters and their likely range, which are important considerations in establishing the architecture of the EPMS. Second, a grower wishing to evaluate a change in management will want to see what the effect will be across the range of weather conditions the crop might encounter. In a related way, future impacts of climate change on water sustainability can be estimated by modifying input variables in the simulation.

On a year-to-year basis, we envisage the model being run with actual (or predicted) weather data to provide estimates of variables such as transpiration that cannot be measured directly by the farmer.

4.2 Key Energy Sustainability Metrics

4.2.1 Identifying the Metrics

As noted earlier, the specific example we will develop here deals with energy use in supplying the cotton crop with water. The whole farm water process model we examined earlier provides boundaries within which lie all the processes associated with crop water management that involve energy.

In light of this, Table 4.2 below presents an analogue of Table 3.1 as follows:

Table 4.2: Possible energy sources for crop water management

	Total Direct Energy Input								
	Total Non-Renewable Energy Input				Renewable Energy Input				
	Total Liquid Fuel Input		Total Electricity and Gas Input						
Energy Categories	Diesel	Petrol	Electricity	Gas	Solar	Wind	Biofuel	Biological	Human
Operations or Processes									
Land-forming									
Channel maintenance									
Cultivating and furrow listing									
Head bay listing									
Pumping from environment									
Pumping for recycling									
Deployment of siphons									

The cells marked in yellow indicate forms of energy currently used for crop water management while those in green are plausible renewable energy alternatives. Most of the cells are self-explanatory, but note that the petrol use is for personnel transport to manage the siphons, which themselves traditionally require human expertise and labour to fill and stop.

The static data type refers to those energy expenditures which, given a particular management environment, are fixed for the field and are determined by the activity. For instance, on a specific farm using specific machinery, the energy cost of forming furrows will remain constant from year to year and can be simply accounted.

The dynamic data type refers to those energy expenditures which occur from time to time, with the timing determined externally. For instance, running the recycling pump to conserve runoff after rain will occur only after reasonably heavy falls; a stochastic event. While the energy cost per unit of pump running time may be relatively constant, the running time will probably depend on the precipitation amount, again part of the stochastic event. As well, the three dynamic data entries will have different times of occurrence. Siphons will be deployed when the crop, responding to environmental cues, requires rewatering. Recycling will possibly occur more frequently, as runoff will follow both irrigation and rainfall. However, given that recycled runoff from rainfall makes up part of the central reserve, pumping from the environment will have a schedule only loosely coupled to the scheduling of irrigation for many growers.

4.2.2 Quantifying the Energy Metrics

In a manner analogous to that proposed for water sustainability, the data values for the static data types can be assembled from farm records and published estimates of energy requirements for different operations. The key issue for the dynamic data values is that the timing is driven by the crop response to weather. Much of the timing and estimates of the pumped volumes can be taken from the crop simulation output. The estimates for pumping water from the environment are derived by the simple accounting of the whole farm water balance, based on simulation model output.

The interdependence between water and energy management is apparent at this point. Not only does the crop water management drive the energy requirements for water management, it is obvious that any strategies to make the farm more efficient with respect to water use will have a positive impact on energy sustainability as well.

As for water, prospective estimates of current energy sustainability and of the impact of changes in farm management will require simulations based on long run weather data. Estimating sustainability for the current crop can be achieved by recourse to adequate farm records of machinery hours, pump times and the like.

Table 1.3: Energy Metrics (Diesel)

Required data	**Type**	**Data source**
Diesel consumption	Dynamic	Machine logs and records
Machinery hours	Dynamic	Meters and farm records
Machinery efficiency		Farm records, energy audits
Diesel cost	Static	Farm records

4.3 Financial sustainability

The data values for financial data can be assembled from farm records and either actual or forecasted market prices for key variables.

5. Applying the EPMS: a simulated case study

5.1 The context

To demonstrate the application of our EPMS to cotton farming, we simulated its application. The site chosen was Myall Vale, for which long run (100 years) weather data was obtained from SILO[8]. A vertosol soil was assumed. DSSAT offered the choice of cultivar Deltapine 555B, which has many of the characteristics of Bollgard II cultivars (Braunack, Bange & Johnston 2012).

Furrow irrigation operating parameters were kindly provided by J. Purcell, Aqua-Tec Consulting and represented traditional commercial practices, which we used for Stage 1 and optimised practices for those fields, which we took as representing Stage 2. The change from Stage 1 to 2 was realistic in that no changes to field layout were required: only siphon management was changed. This resulted in inflow rates increasing from 2.8 L/s to 6.0 L/s for each furrow and cutoff times being reduced from 745 minutes to 310 minutes. However, we also assumed that the farmer would take a holistic view and, predicting that the altered irrigation management would result in more runoff, would improve the overall efficiency of recycling the runoff water, from 75% to 85%. We also assumed some optimisation of the land forming operations required to set up for furrow irrigation and have reduced those in line with trends shown in Khabbaz (2010).

[8] SILO is an enhanced climate database hosted by The Science Delivery Division of the Department of Science, Information Technology, Innovation and the Arts (DSITA), providing Australian climate data from 1889 to the present (Department of Science- Information-Technology Innovation and the Arts 2014).

Economic data was adapted from a sample budget for furrow-irrigated cotton in 2014-2015 (NSW Department of Primary Industries 2015). We also assumed that only licensed water was taken from the environment.

The process of applying the EPMS was as follows. First, SIRMOD was run to determine water infiltration and runoff characteristics for each irrigation event. These data were used as additional inputs to DSSAT, which cycled through the 100 years' weather data. We treated each crop as unique, i.e. the model was reset to the same starting conditions for each crop so that the simulation provided data on the same crop grown concurrently under 100 different weather conditions. The output was aggregated and applied to WESM, which is essentially a spreadsheet exercise. Statistical analysis of the runs for Stage 1 vs Stage 2 allowed us to ask whether the change in irrigation practice had, on average, across all likely weather conditions, resulted in an improvement in sustainability performance.

5.2 Water sustainability

5.2.1 Results

The following description of the results for water sustainability (Table 5.1) should be read in conjunction with the diagrammatic representation of WESM given in the Appendix.

Table 2.1: WESM results by level of decomposition

Parameter	Stage 1	Stage 2	t	p	Dif	Dif(%)
WESM Level 1						
Profit/WaterCost Ratio	**4.40**	**6.98**	**-7.055**	**<0.001**	**2.57905**	**59%**
WESM Level 2						
Return on Water ($/ML)	$ 78.04	92.20524	-3.858	<0.01	14.17022	18%
Water Use Leverage	0.58	0.44	8.484	<0.001	-0.14	-24%
Weighted Average Irrigation Cost ($/ML)	32.24	32.24				
WESM Level 3						
Profit Margin	0.22	0.25	-3.632	<0.001	0.02801	11%
Economic Water Use Index ($/ML)	$ 352.03	$ 369.15	-3.024	<0.01	17.12	5%
WESM Level 4						
Operating Profit ($/ha)	**$1,024.58**	**$1,158.15**	**-3.118**	**<0.01**	**$133.57**	**13%**
Crop Water Use Index (Kg lint/ML)	137.08	143.74	-3.024	<0.01	6.66	5%
Weighted Average CottonPrice ($/kg lint)	$1.03	$1.03				

Parameter	**Stage 1**	**Stage 2**	**t**	**p**	**Dif**	**Dif(%)**
WESM Level 5						
Total Operating Cost ($/ha)	$3,605.58	$3,478.71				
Total Sales Revenue ($/ha)	$4,630.16	$4,636.86	-0.151	n.s.	$6.70	0%
Water Input Efficiency	**0.350**	**0.372**	**-3.960**	**<0.001**	**0.020**	**6%**
Transpiration Index (Kg biomass/ML)	**2599.68**	**2628.55**	**-1.288**	**n.s.**	**28.88**	**1%**
Harvest Index	**0.151**	**0.147**	**3.658**	**<0.001**	**0.000**	**-2%**
WESM Level 6						
Total Water Cost ($/ha)	**$244.83**	**$177.77**	**9.903**	**<0.001**	**-$67.06**	**-27%**
Other Variable Costs ($/ha)	$444.44	$407.13	5.742	<0.001	-$37.32	-8%
Sales revenue (lint) ($/ha)	$3,764.74	$3,770.19	-0.151	n.s.	$5.44	0%
Sales Revenue (seed)($/ha)	$865.41	$866.67	-0.151	n.s.	$1.25	0%
Crop Water Loss/Crop Water Supply	0.571	0.428				
Recycled Runoff to Crop Water Supply	0.081	0.202				
WESM Level 7						
Lint Yield (kg/ha)	1802.95	1805.55	-0.151	n.s.	2.61	0%
Cottonseed Yield (kg/ha)	2704.42	2708.33	-0.151	n.s.	3.91	0%
Traded Water (ML/ha)	0	0				
Licensed Water (ML/ha)	7.59	5.51	9.903	<0.001	-2.08	-27%
Abstracted Environmental Water (ML/ha)	**7.59**	**5.51**	**9.903**	**<0.001**	**-2.08**	**-27%**

Parameter	**Stage 1**	**Stage 2**	**t**	**p**	**Dif**	**Dif(%)**
Inputs to WESM from DSSAT						
Total Biomass (kg/ha)	11947.77	12269.72	-2.896	<0.01	321.95	3%
Total Seedcotton Yield (kg/ha)	4507.37	4513.89	-0.151	n.s.	6.52	0%
Rainfall (ML/ha)	4.57	4.57	-0.009	n.s.	0.00	0%
Irrigation (ML/ha)	8.66	8.06	2.769	<0.01	-0.60	-7%
Transpiration (ML/ha)	4.61	4.69	-1.133	n.s.	0.07	2%
Soil Evaporation (ML/ha)	6.24	6.10	1.144	n.s.	-0.15	-2%
Deep Drainage (ML/ha)	**1.01**	**0.04**	**18.793**	**<0.001**	**-0.97**	**-96%**
Runoff from rainfall (ML/ha)	0.52	0.53	-0.052	n.s.	0.00	1%
Runoff from Irrigation (ML/ha)	0.90	2.47	-31.933	<0.001	1.57	174%
Change in Soil Water Storage (ML/ha)	-0.06	-1.19	15.875	<0.001	-1.13	1938%

Note: The parameters are arranged as for the diagram in the Appendix. The columns show data for Stages 1 and 2, the value of the univariate one-tailed t-test used to compare these, the associated probability and the extent of variation between stage values.

The overall summary parameter, Profit to Water Cost Ratio increased significantly from 4.4 to 7.0, a 59% increase, indicating that, on average, the improved irrigation practice would improve overall water sustainability. This increase resulted from a slight but significant increase in profit ($1024/ha to $1158/ha, 13%) and a significant decrease in water licence costs ($245/ha to $177/ha; -27%).

The small increase in profit has not come from any increase in yield and hence sales revenues, but largely from a decrease in pumping costs (this is elaborated when we consider energy sustainability later) and a small decrease in the cost of land preparation.

The decrease in water licence costs comes from increased efficiency in the crop water management system. A major source of water loss, deep drainage, has been almost totally curtailed. Together with greater use of soil water storage, this accounts for most of the 2 ML/ha reduction in water abstracted from the environment.

Part of the reason we obtained this result is that we used SIRMOD and DSSAT together in a way that allowed the variation in infiltration from furrow irrigation down the furrow length to be simulated rather than assuming that the field was irrigated the same throughout. The change in irrigation management referred to earlier provided infiltration that varied much less with distance down the furrow than in the un-improved case. This allowed more efficient use of soil water, which is estimated as an average over the whole field. Less uniform irrigation would mean that there would be excessive water stored in some parts of the soil.

In turn, this lead to a small but significant improvement in Water Input Efficiency (see Equation 3), from 0.35 to 0.37.

5.2.2 Consequences

While the summary parameter, PWCR, suggests that we have improved sustainability of crop water use, we can now probe this more deeply. Equation set 1 laid out the criteria for environmental sustainability, against which we can assess the impact of the irrigation management change.

i. The parameters used in the simulation model were intended to allow for no limit to crop growth other than water and, ideally, the irrigation scheduling rules in the model should have prevented that. Therefore, yield should be close to Ymax. This claim could be checked against historical best yields for the crop in similar locations (Constable & Bange 2015). The result that yield did not improve with better irrigation management does, however, bear further scrutiny, as one would expect a greater proportion of the field to be performing at least as well as the best portions of the traditionally irrigated field. Future work might examine a better optimization of the irrigation scheduling rules between Stages 1 and 2 to see if this can be achieved: in this simulation, the same rules were used for both.

ii. The relationship between crop water supply (P+I) and transpiration is indicated by water input efficiency (Equation set 3). This did show some improvement, but the result begs the question: how far can this be improved using furrow irrigation? Deep drainage appears to have been almost eliminated (Equation 1), but soil evaporation still dominates the loss of water from the field. Given that this is driven by wetting of the soil surface by both rainfall and surface flow irrigation, it would appear that the extent of soil evaporation will always remain a major limitation on achieving CWS=T. A different irrigation technology such as subsurface drip irrigation that does not wet the soil surface may provide some further improvement in this parameter.

iii. Equation 1 indicates that surface runoff should approach zero. Runoff is unlikely to be eliminated from a surface flow irrigation system, so an effective system to capture and recycle it is essential if this condition is to be met. Such a system will also capture runoff from rainfall. The overall effectiveness then depends on the efficiency of recovery of water by the recycling system, not often a critical focus of crop water management.

iv. Finally, equation 1 indicates that water abstracted from the environment should show a marked downward trend and, indeed, a 27% reduction was observed. This is also reflected in the reduction in Water Use Leverage, which, in a manner analogous to its financial origins, describes the extent to which the crop is financially “in debt” to the environment, that is, the extent to which the crop depends on environmentally-sourced water. A decrease in this parameter to its target value of zero represents improvement in sustainability.

Overall, there is evidence for an improvement in crop water management sustainability as a consequence of moving from Stage 1 to Stage 2, but it also suggests there will be limits on how much improvement can be achieved. Complete environmental sustainability is unlikely without further technology change.

The question of whether economic sustainability has been improved is largely an accounting one from this stage and depends heavily on where the boundary of the system under consideration is drawn. Our focus has largely been on the field and here we show no impairment and a slight improvement in the operating surplus achieved. However, a wider boundary that includes other farm-wide costs and possible investments in new technology may require a larger field operating surplus for the organization to be economically sustainable. Accounting for these additional outlays is probably not trivial, but is nonetheless accessible practice and it may be possible to strike a threshold of field operating surplus that will adequately provide for organisational economic sustainability.

5.3 Sustainable use of energy for crop water management

The results for calculation of a summary parameter, Profit/Energy Cost Ratio (PECR) , analogous to PWCR but incorporating only that energy use attributable to crop water management is shown in Table 5.2. Recall that this examines the effects of management decisions that would have been made to improve crop water sustainability and, for that reason, is driven by those decisions. A more complete energy optimisation would have, as its origin, a direction to improve energy sustainability and thus would have greater influence on the decomposition model. However, we also recall from earlier sections that energy use associated with crop water management is the single biggest category of direct energy use in cotton growing, so the results presented here will have a significant effect on farm sustainability.

In the calculations, we assumed that the only energy source under consideration was distillate.

The summary parameter, PECR, indicates a trend of improving economic and environmental sustainability. The profit, again, is modestly improved and this is due, approximately equally, to savings in water licence costs and water management costs. With respect to the latter, because the water management required less environmental abstraction, the pumping cost associated with that has been significantly reduced, but has been somewhat offset by the extra recycling pumping that the changed irrigation practice implied. Overall, though, there has been a contribution, through reduced costs, to improving the economic sustainability of energy use. We note that the data is very site specific as any variation in pumping head for either water abstraction (eg, from a river to a bore) or recycling will have profound effects on pump energy requirements.

Equation 2 indicated that environmental sustainability of energy use requires that aggregate non-renewable energy inputs should tend to zero. This can be achieved in two ways: either by substituting renewable energy or by decreasing the quantum of energy required, or both. In this case, the Energy Use Leverage was set to unity, by design, indicating that no renewable energy use was included. However, the reduced energy cost per hectare reflects a reduced energy input, which is a constructive trend.

Table 5.2: WESM results by level of decomposition

As for Table 5.1, with the addition of further lines (coloured) showing key parameters for energy use associated with crop water management.

Parameter	**Stage 1**	**Stage 2**	**t**	**p**	**Dif**	**Dif(%)**
WESM Level 1						
Profit/WaterCost Ratio	**4.40**	**6.98**	**-7.055**	**<0.001**	**2.57905**	**59%**
Profit/Energy Cost Ratio	**3.15**	**4.37**	**-6.391**	**<0.001**	**1.21821**	**39%**
WESM Level 2						
Return on Water ($/ML)	$78.04	$92.21	-3.858	<0.01	14.17022	18%
Water Use Leverage	0.58	0.44	8.484	<0.001	-0.14	-24%
Weighted Average Irrigation Cost ($/ML)	32.24	32.24				
Return on Energy ($/MJ)	$0.13	$0.18	-6.391	<0.001	0.0505	39%
Energy Use Leverage	1	1				
Weighted Average Energy Cost ($/MJ)	$0.04	$0.04				
WESM Level 3						
Profit Margin	0.22	0.25	-3.632	<0.001	0.02801	11%
Economic Water Use Index ($/ML)	$352.03	$369.15	-3.024	<0.01	17.12	5%
Economic Energy Use Index ($/MJ)	$0.59	$0.72	-9.16509	<0.001	$0.13	23%
WESM Level 4						
Operating Profit ($/ha)	**$1,024.58**	**$1,158.15**	**-3.118**	**<0.01**	**$133.57**	**13%**
Crop Water Use Index (Kg lint/ML)	137.08	143.74	-3.024	<0.01	6.66	5%
Weighted Average CottonPrice ($/kg lint)	$1.03	$1.03				

Parameter	**Stage 1**	**Stage 2**	**t**	**p**	**Dif**	**Dif(%)**
WESM Level 5						
Total Operating Cost ($/ha)	$3,605.58	$3,478.71				
Total Sales Revenue ($/ha)	$4,630.16	$4,636.86	-0.151	n.s.	$6.70	0%
Water Input Efficiency	**0.350**	**0.372**	**-3.960**	**<0.001**	**0.020**	**6%**
Transpiration Index (Kg biomass/ML)	**2599.68**	**2628.55**	**-1.288**	**n.s.**	**28.88**	**1%**
Harvest Index	**0.151**	**0.147**	**3.658**	**<0.001**	**0.000**	**-2%**
WESM Level 6						
Total Water Cost ($/ha)	**$244.83**	**$177.77**	**9.903**	**<0.001**	**-$67.06**	**-27%**
Other Variable Costs ($/ha)	$444.44	$407.13	5.742	<0.001	-$37.32	-8%
Sales revenue (lint) ($/ha)	$3,764.74	$3,770.19	-0.151	n.s.	$5.44	0%
Sales Revenue (seed)($/ha)	$865.41	$866.67	-0.151	n.s.	$1.25	0%
Crop Water Loss/Crop Water Supply	0.571	0.428				
Recycled Runoff to Crop Water Supply	0.081	0.202				
Pumping cost for water abstraction ($/ha)	$213.09	$154.72	9.903	<0.001	-$58.37	-27%
Pumping cost for water recycling ($/ha)	$15.00	$35.74	-35.149	<0.001	$20.74	138%
Land preparation assoc. with water management ($/ha)	$104.31	$81.18				
Total energy cost for water management ($/ha)	$332.40	$271.64			-$60.76	
WESM Level 7						
Lint Yield (kg/ha)	1802.95	1805.55	-0.151	n.s.	2.61	0%
Cottonseed Yield (kg/ha)	2704.42	2708.33	-0.151	n.s.	3.91	0%
Traded Water (ML/ha)	0	0				
Licensed Water (ML/ha)	7.59	5.51	9.903	<0.001	-2.08	-27%
Abstracted Environmental Water (ML/ha)	**7.59**	**5.51**	**9.903**	**<0.001**	**-2.08**	**-27%**

Parameter	**Stage 1**	**Stage 2**	**t**	**p**	**Dif**	**Dif(%)**
Inputs to WESM from DSSAT						
Total Biomass (kg/ha)	11947.77	12269.72	-2.896	<0.01	321.95	3%
Total Seedcotton Yield (kg/ha)	4507.37	4513.89	-0.151	n.s.	6.52	0%
Rainfall (ML/ha)	4.57	4.57	-0.009	n.s.	0.00	0%
Irrigation (ML/ha)	8.66	8.06	2.769	<0.01	-0.60	-7%
Transpiration (ML/ha)	4.61	4.69	-1.133	n.s.	0.07	2%
Soil Evaporation (ML/ha)	6.24	6.10	1.144	n.s.	-0.15	-2%
Deep Drainage (ML/ha)	**1.01**	**0.04**	**18.793**	**<0.001**	**-0.97**	**-96%**
Runoff from rainfall (ML/ha)	0.52	0.53	-0.052	n.s.	0.00	1%
Runoff from Irrigation (ML/ha)	0.90	2.47	-31.933	<0.001	1.57	174%
Change in Soil Water Storage (ML/ha)	-0.06	-1.19	15.875	<0.001	-1.13	1938%

6. The EPMS in practice

6.1 Why use it?

In this section, we tackle the question of why would a cotton producer actually use the EPMS we have described, either as is, or further developed to include a comprehensive suite of natural resources. The general principles remain the same.

A. The first viable use is in the context in which it has been described in earlier sections, that is, as a strategic guide quantifying the effect of proposed changes in practice or investment in new technology on overall environmental and economic sustainability of the farm. The summary parameters, i.e. PWCR, PECR and further parameters for other natural resources provide this quantification, but with some constraints on their use.

   In few industries, if any, is production so inextricably linked to the weather as it is in agriculture. The impact of this on, say PWCR, is obvious from a simple thought experiment. Imagine two years in which overall radiation receipts and temperature averages are similar and support crop growth to the same extent, but one year is quite wet and the other quite dry. We can imagine that profit will be similar in each year, but in one, much of the water requirement might be met from rainfall (in our simulations, there were about 4 years in the 100 in which this was the case) while the other year will depend heavily on abstracted water for irrigation. Thus, in the calculation of PWCR, both years will have similar numerators, but quite different denominators and hence have quite different results.

We observed this year-to-year volatility in PWCR, which reduces its value as a unique indicator for sustainability in any given year. However, we also observed, that for every year in the simulation, the Stage 2 value for PWCR was significantly greater than that for Stage 1. In other words, we think the long term average result, based on an extensive sampling of the weather data at the site, provides a sound expression of overall sustainability, particularly when assessing the impact of, for example, a management change.

In this context, organisational and operational decisions align obviously. Suppose, for instance, that the hypothetical farm used in our analysis decided, at a strategic level, to modify irrigation practice. Consequential operational decisions logically follow: modify siphons, train field hands, etc.

B. The EPMS has, annual volatility in PWCR notwithstanding, utility in assessing, if operations in the crop just finished were carried out in a way that should have maintained the potential improvements in sustainability, in retrospect. In this case, elements of the decomposition analysis are more useful than the summary parameter. For instance, Water Input Efficiency should be trending around the predicted long term average for this Stage. Because it is a ratio, weather-dependent variation in water flows will not affect the result. The same will hold true for other ratios (TI, HI). Should a key ratio be found to have been at some departure from its target, this provides a clear indication of where actual operational practices need to be scrutinized.

An annual activity-based costing analysis will enable cost and price variations to be tracked and their economic impact assessed.

C. The EPMS has limited utility on a day-to-day operational basis. Its main value is possibly in providing motivation to ensure the desired operations are carried out with the appropriate attention to detail and practice.

6.2 Data

Any quantitative assessment of organisational performance requires data to enable objective, quantifiable judgments to be made. In earlier sections (Quantifying the Water Metrics, Quantifying the Energy Metrics), dynamic and static data were identified.

A central part of this project was the use of a crop simulation model that allowed the effects of variable weather conditions to be assessed. Essentially all management options that impact directly the growth of the plant (water, fertiliser, soil management etc.) will be included in this way as their effects will be modified by the weather. The limitation then is finding a simulation model that allows such inclusions.

We used DSSAT because we found APSIM-OZCOT gave theoretically impossible estimates of transpiration in a significant fraction of the runs. This deficiency was unable to be fixed by CSIRO, so we turned to DSSAT (Jones et al. 2003) which is maintained in an open-source community and has been used for cotton simulation in Australia previously. Weather data is adequately available from SILO and the major issues are finding appropriate cultivar-specific growth parameters and soil data. The latter is a common problem but should improve as more open-access data is made available (Jones et al. 2003). There are methods to calibrate the growth parameters in the model for specific cultivars, using field crop data. This only needs to be done once for each cultivar. (A similar problem exists for APSIM-OZCOT.)

We also used a commercial statistics package to collate the annual output data into long term averages. This could be replaced with a purpose-built app.

Nonetheless, running simulation models either for long term effects or to estimate transpiration and drainage for the preceding crop is not a routine procedure for farmers and their advisors. Given that there is no other practical way to gather such data, without which sustainability is only being guessed at, there is justification for examining what provision of this service on a commercial basis might require for it to be both effective and sustainable.

Similarly, we used SIRMOD to prepare furrow irrigation data as inputs for DSSAT. Again, using this is not routine in the industry, but is a service that can be accessed through providers such as Aqua-Tec Consulting. The driver for answering these questions is: Is it worth it? We look at this in the final section.

6.3 Goals and targets

Output from the EPMS is of little value without reference points. Two broad categories of issues remain to be resolved.

A. *A priori* setting of performance expectations. For some of the key sustainability indicators we have identified, there is a theoretical limit at which no further improvement is possible. For instance, WIE = 1. This value is based on sound theory and is accessible to all stakeholders. In contrast, there is a suite of parameters such as Return on Water for which no unambiguous limit can be derived. We need to decide therefore (i.e. make a judgment) as to what value such parameters should take optimally.

B. Even when a range of values has been derived or chosen, as we have noted earlier, it may be advantageous from an industry perspective to have intermediary goals that become waypoints on a trajectory of increasing sustainability. For instance, for furrow irrigation, what is the maximum value of WIE that can be achieved? The question then arises: how are these goals to be determined and set? For those based on theory, one could imagine, for instance, performing simulation with all operating parameters set optimally for that technology.

7. Sustainability Analysis of the Cotton Farm

In this section, we consider what information the EPMS results give us regarding the sustainability of the cotton farm we have modelled. We note that the cotton farm is hypothetical, but the results allow us to suggest the sort of sustainability analysis that one could undertake for farms that have been more specifically modelled.

7.1 Was the farm sustainable with respect to water use?

The criteria for sustainability in water use have been set out in Equation 1. The irrigation management was designed to provide yield unlimited by water, so we will assume for now that we achieved the criterion in the first line of Equation 1, even though we have elsewhere argued that this might not be completely accurate due to sub-optimal parameter choice in the model.

Crop water supply (CWS) was about three times the transpiration for both stages, so this element of the criterion was clearly not met. This is a consequence of the type of irrigation methodology and the partitioning of rainfall into infiltration and runoff.

For both stages, runoff was recycled, so its value tended to a minimum set by the efficiency of the recycling system. In theory, this should have been zero, but we calculated that seepage and evaporative losses were 0.35 and 0.45 ML/ha for stage 1 and 2 respectively. These values are possibly the minima we should expect for runoff.

Deep drainage was only a minor component (8%) of crop water supply in stage 1 and was almost completely eliminated from stage 2. However, soil evaporation from wet soil surfaces comprised about 50% of crop water supply thus was at some departure from zero.

As a result, while abstracted water (AEW) did decrease by 27% by moving from stage 1 to 2, it still was significantly different from zero for both stages (e.g. stage 5 sustainability target). We can very roughly estimate what the minimum value for AEW might be on this farm by working out the water balance assuming soil evaporation from irrigation were eliminated and all rainfall was effectively used. There would still be soil evaporation from rainfall, which we have guessed at 50%. This leaves a shortfall of transpiration beyond rainfall of about 2 ML/ha, which would be the minimum long term average AEW and might only be achieved with stage 4 technology.

On that basis, the change in practice from stage 1 to stage 2 has shifted the overall water sustainability of the farm about 35% of the range it needs to traverse to reach its long-term maximum sustainability target. As noted elsewhere, a change in irrigation technology will be required to make further significant improvements.

7.2 Was the farm sustainable with respect to energy required for crop water management?

Equation 2 provides the over-riding criterion for sustainability with respect to energy use. We calculated a decrease in energy required for crop water management from 8 to 6.6 GJ/ha. This was due to a small decrease in land preparation energy, which we assumed, and a large decrease in pumping energy because of the decrease in water abstraction from the environment. However, 6.6 is still quite distant from zero, the sustainability target.

There are a number of ways in which this performance could be improved. The assumption we made was that all energy was from non-renewable sources. However, recent developments in solar power use for pumping[9] suggest that a significant proportion of the energy required for water abstraction might be met from renewable sources. At a maximum for this hypothetical farm, that might provide about 3.7 GJ/ha, reducing the non-renewable energy requirement for water management to 2.9 GJ/ha, a significant shift from 8 GJ/ha towards zero.

7.3 Economic Impact.

At the beginning of this report, we discussed the value of sustainability to Australian cotton growers. Certainly the argument concerning licence to operate remains valid and we have developed a process that provides theoretically sound, objective evidence to support this.

The prospects of financial gain flowing through the supply chain seem, at the moment, remote. Our demonstration suggests that, at least, we have preserved the farm's economic sustainability. However, beyond this, there may be significant local gains to the domestic industry and its attendant communities. The following proximate analysis is based on the data presented so far and ABS (2015) statistics. The latter were used to obtain an average irrigated industry size over the period 2010-2014.

[9] See for example, http://www.cottoninfo.com.au/sites/default/files/documents/Andrew%20Gill%20solar%20case%20study.pdf

Table 3.1 Environmental, production and economic gain if all cotton farming moved from the furrow irrigation practices of Stage 1 to Stage 2.

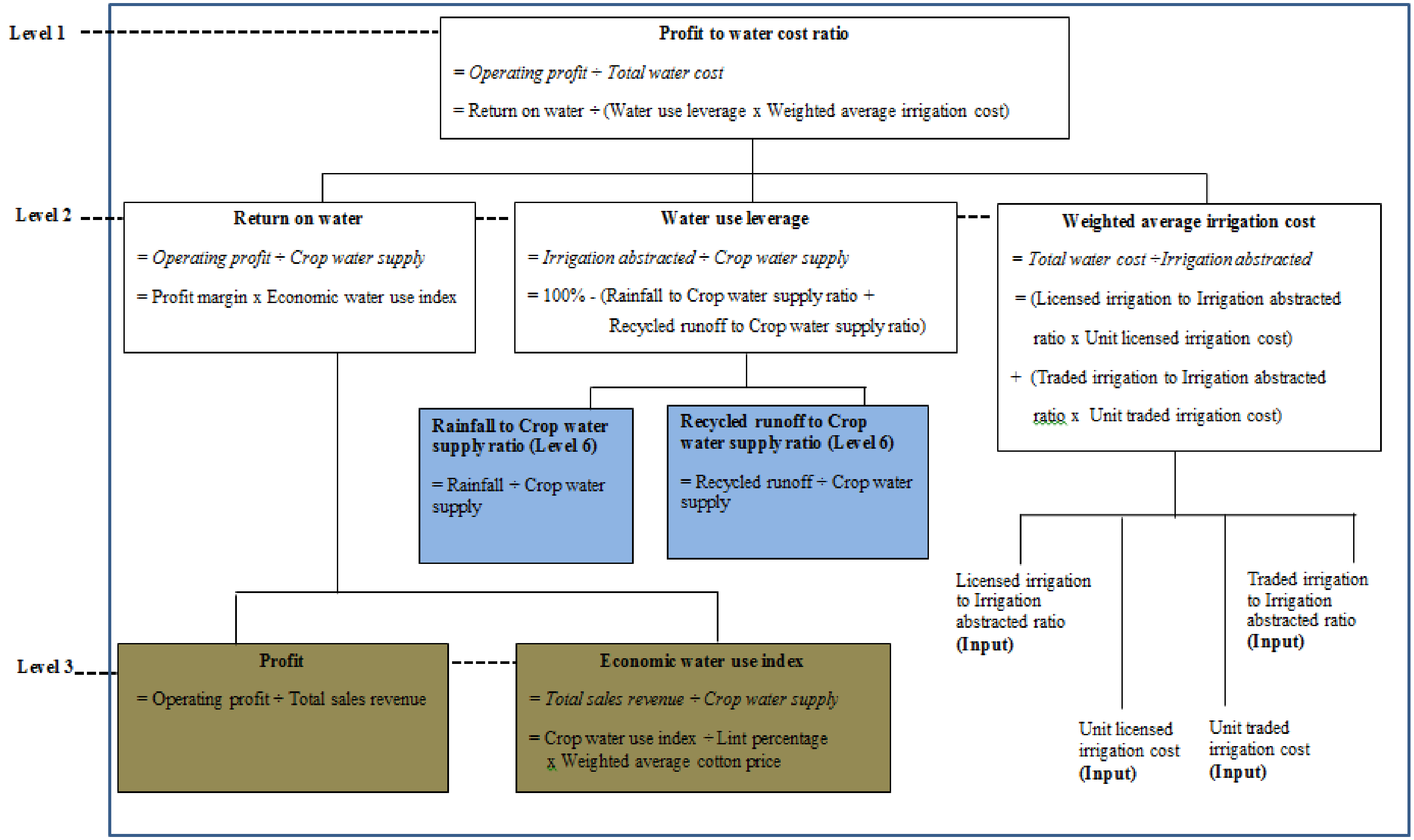
Size of analysis			**Per ha**	**Business level**	**Industry level**
Cotton irrigated area (ha)			1	400	365,365
Potential environmental gain	Water volume saving	=Decrease in crop water lost =2.15 ML/ha	2.15 ML	860 ML	785535 ML
Potential crop production gain	Gain in lint production (by using saved water)	=Crop water saved (ML/ha) x Crop water use index (kg lint/ML) =2.15 ML x 144 kg/ML =310 kg lint/ha	310 kg (1.36 bales)	124000 kg (546 bales)	113263150 kg (498957 bales)
	Gain in lint production (based on improved practice)	=Increase in lint yield =2.6 kg/ha	2.6 kg	1040 kg (4.6 bales)	949949 kg (4185 bales)
	Total gain in lint production		312.6 kg (1.37 bales)	125040 kg (550 bales)	114213099 kg (503141 bales)
Potential economic gain	Gain in operating profit (from additional water resource)	=Crop water saved (ML/ha x Return on water (($/ML) =2.15 ML/ha x $92.20/ML =$198/ha	$198	$79,292	$72,426,304
	Gain in operating profit (based on improved practice)	=Increase in operating profit =$134	$134	$53,428	$48,801,803
	Total gain in operating profit		$332	$132,720	$121,228,107

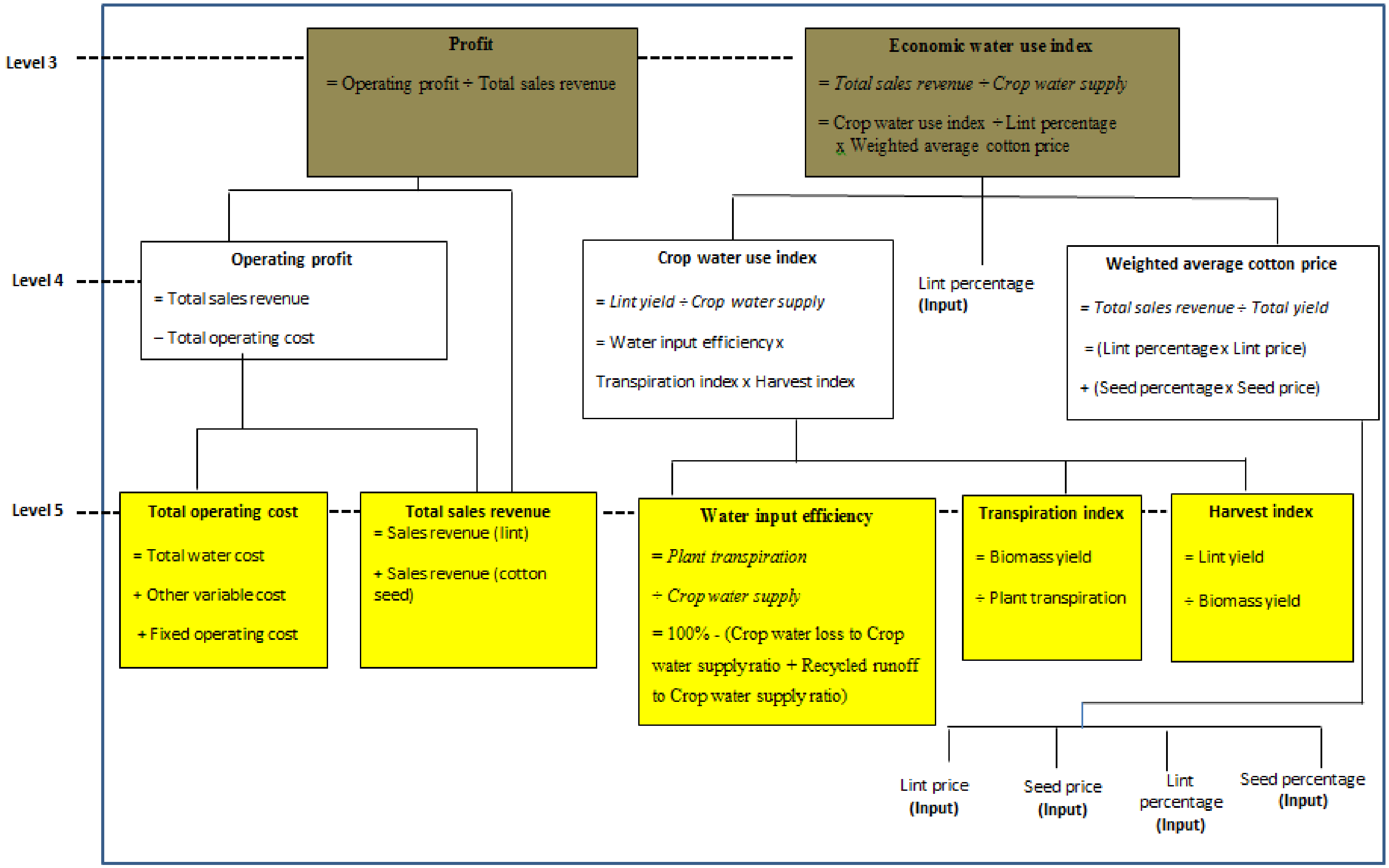
The basis of the overall gains in production and operating profit is that production is more often constrained by water than land. Therefore, more efficient use of water on land currently farmed, results in gains on that land, plus additional outputs from new land that is efficiently irrigated with the saved water. The analysis is naive in that it treats the industry as monolithic and unimproved, but it does suggest that there are significant industry-wide gains in profitability that can be achieved as a consequence of improving efficiency of use of a natural resource.

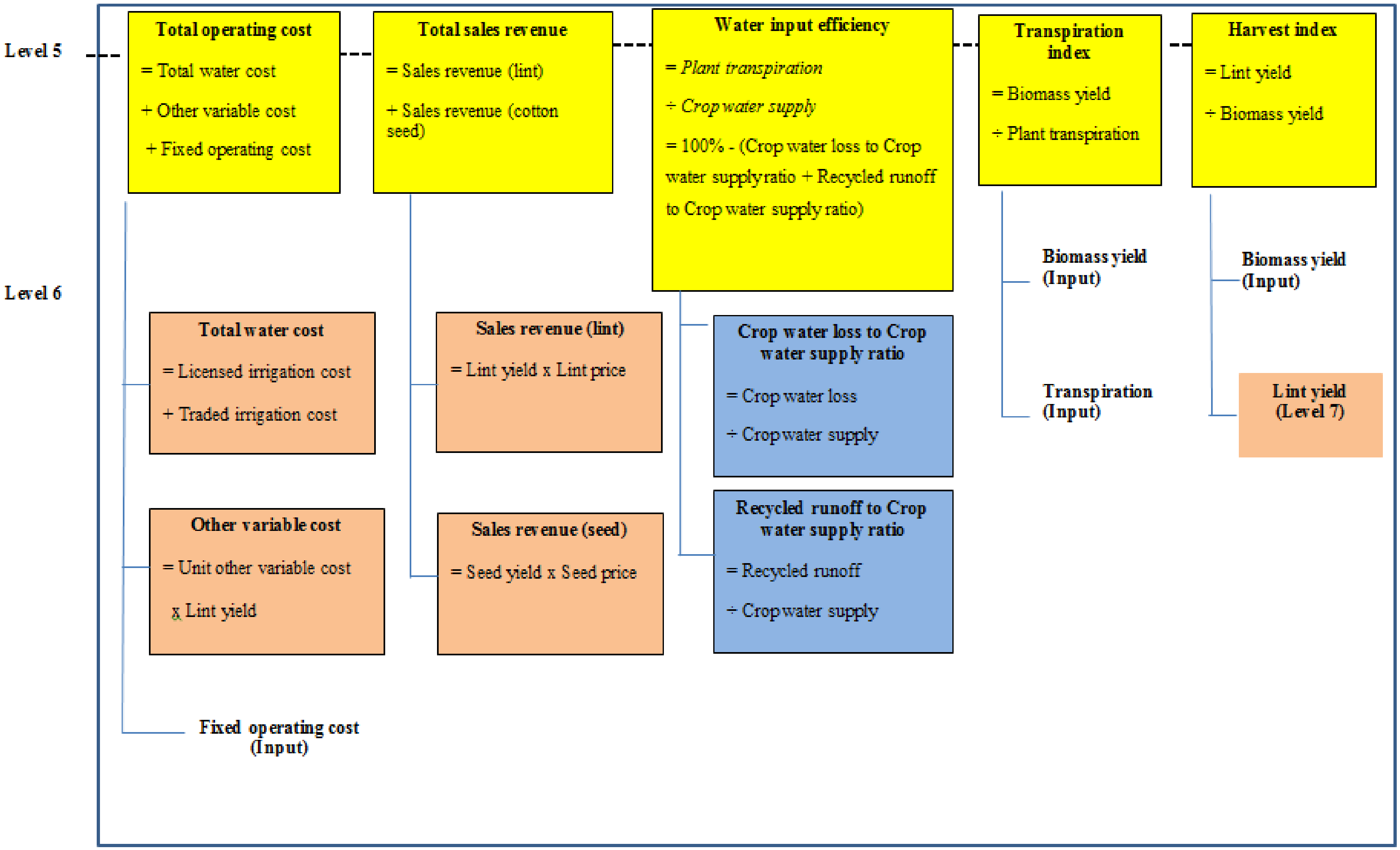
However, if we inspect with a view to sustainability rather than simply efficiency, a somewhat different picture emerges. Recall that a major criterion of sustainable water use was to reduce the footprint of cotton production on the water resource. The reduction in water loss of 2.15 ML/ha translates to a reduction in water abstraction of 2.08 ML/ha and this represents the improvement in water sustainability of the cotton farm. An argument might be raised that this water should not be abstracted and therefore would not be available to the farmer to produce extra profit. However, the gains in efficiency of production necessary to achieve improved water sustainability have themselves reduced costs and lead to improved profits, which can be retained by the industry. In this case, both environmental and economic sustainability of the farm have been improved.

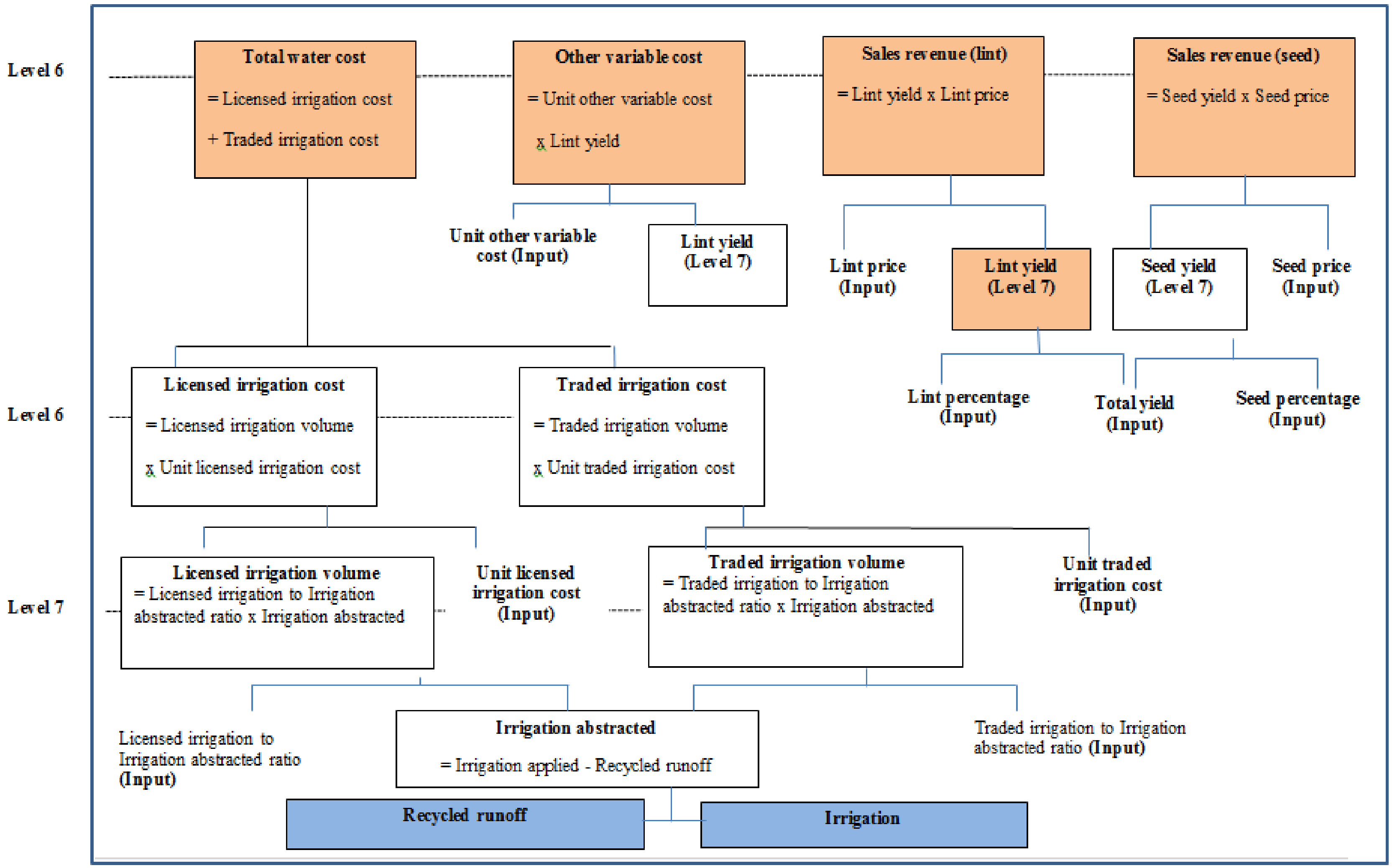
In this research we set out the architecture of an EPMS with a focus on water and a subset of energy (direct energy in irrigation). An extension of the work would be to apply our approach to nitrogen management, noting that the nitrogen cycle for cotton has significant linkages with water management of a cotton crop.

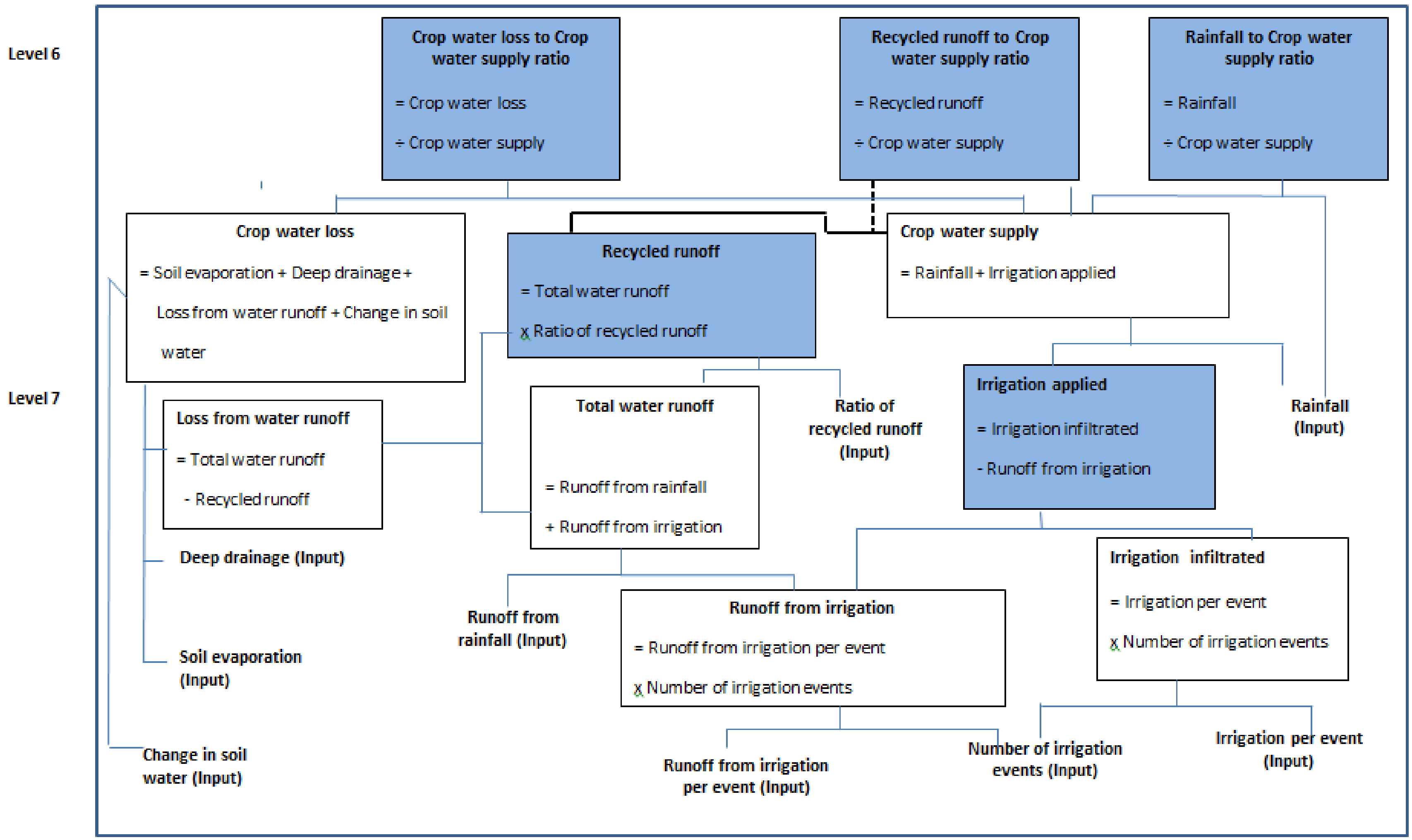
Appendix: WESM diagram




Level 3
Level 4
Level 5
Profit
= Operating profit ÷ Total sales revenue
Economic water use index
= Total sales revenue ÷ Crop water supply
= Crop water use index ÷ Lint percentage x Weighted average cotton price
Operating profit
= Total sales revenue
– Total operating cost
Crop water use index
= Lint yield ÷ Crop water supply
= Water input efficiency x Transpiration index x Harvest index
Lint percentage (Input)
Weighted average cotton price
= Total sales revenue ÷ Total yield
= (Lint percentage x Lint price)
+ (Seed percentage x Seed price)
Total operating cost
= Total water cost
+ Other variable cost
+ Fixed operating cost
Total sales revenue
= Sales revenue (lint)
+ Sales revenue (cotton seed)
Water input efficiency
= Plant transpiration
÷ Crop water supply
= 100% - (Crop water loss to Crop water supply ratio + Recycled runoff to Crop water supply ratio)
Transpiration index
= Biomass yield
÷ Plant transpiration
Harvest index
= Lint yield
÷ Biomass yield
Lint price (Input)
Seed price (Input)
Lint percentage (Input)
Seed percentage (Input)


Level 5
Level 6
Total operating cost
= Total water cost
+ Other variable cost
+ Fixed operating cost
Total sales revenue
= Sales revenue (lint)
+ Sales revenue (cotton seed)
Water input efficiency
= Plant transpiration
÷ Crop water supply
= 100% - (Crop water loss to Crop water supply ratio + Recycled runoff to Crop water supply ratio)
Transpiration index
= Biomass yield
÷ Plant transpiration
Harvest index
= Lint yield
÷ Biomass yield
Total water cost
= Licensed irrigation cost
+ Traded irrigation cost
Other variable cost
= Unit other variable cost
x Lint yield
Fixed operating cost (Input)
Sales revenue (lint)
= Lint yield x Lint price
Sales revenue (seed)
= Seed yield x Seed price
Crop water loss to Crop water supply ratio
= Crop water loss
÷ Crop water supply
Recycled runoff to Crop water supply ratio
= Recycled runoff
÷ Crop water supply
Biomass yield (Input)
Transpiration (Input)
Biomass yield (Input)
Lint yield (Level 7)


Level 6
Total water cost
= Licensed irrigation cost
+ Traded irrigation cost
Other variable cost
= Unit other variable cost
x Lint yield
Sales revenue (lint)
= Lint yield x Lint price
Sales revenue (seed)
= Seed yield x Seed price
Unit other variable cost (Input)
Lint yield (Level 7)
Lint price (Input)
Lint yield (Level 7)
Seed yield (Level 7)
Seed price (Input)
Lint percentage (Input)
Total yield (Input)
Seed percentage (Input)
Level 6
Licensed irrigation cost
= Licensed irrigation volume
x Unit licensed irrigation cost
Traded irrigation cost
= Traded irrigation volume
x Unit traded irrigation cost
Level 7
Licensed irrigation volume
= Licensed irrigation to Irrigation abstracted ratio x Irrigation abstracted
Unit licensed irrigation cost (Input)
Traded irrigation volume
= Traded irrigation to Irrigation abstracted ratio x Irrigation abstracted
Unit traded irrigation cost (Input)
Licensed irrigation to Irrigation abstracted ratio (Input)
Irrigation abstracted
= Irrigation applied - Recycled runoff
Traded irrigation to Irrigation abstracted ratio (Input)
Recycled runoff
Irrigation



Level 6
Crop water loss to Crop water supply ratio
= Crop water loss
÷ Crop water supply
Recycled runoff to Crop water supply ratio
= Recycled runoff
÷ Crop water supply
Rainfall to Crop water supply ratio
= Rainfall
÷ Crop water supply
Crop water loss
= Soil evaporation + Deep drainage +
Loss from water runoff + Change in soil
water
Recycled runoff
= Total water runoff
x Ratio of recycled runoff
Crop water supply
= Rainfall + Irrigation applied
Level 7
Loss from water runoff
= Total water runoff
- Recycled runoff
Total water runoff
= Runoff from rainfall
+ Runoff from irrigation
Ratio of recycled runoff (Input)
Irrigation applied
= Irrigation infiltrated
- Runoff from irrigation
Rainfall (Input)
Deep drainage (Input)
Irrigation infiltrated
= Irrigation per event
x Number of irrigation events
Runoff from rainfall (Input)
Runoff from irrigation
= Runoff from irrigation per event
x Number of irrigation events
Soil evaporation (Input)
Change in soil water (Input)
Runoff from irrigation per event (Input)
Number of irrigation events (Input)
Irrigation per event (Input)

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UNIVERSITY OF TECHNOLOGY SYDNEY

Australian Cotton: Accounting for value chain sustainability and competitive advantage

Third Year Report

Diffusion of best practices in the Australian Cotton Industry: Lessons learnt

February 2015

This third year report has been submitted to the Cotton Research and Development Corporation (CRDC) as part of the project: Australian Cotton: Accounting for value chain sustainability and competitive advantage (CRDC reference code: UTS1201). The project is jointly funded with UTS Business School.

Please note, feedback from the CRDC and other key stakeholders will be incorporated into an updated version if the report is subject to general release.

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Disclaimer: The report is intended for internal use by CRDC and Cotton Australia only.
Users are reminded of the need to ensure that information upon which they rely is up to date and appropriate. Further, the recommendations in this report are of a general nature, and accordingly the authors encourage readers to seek independent advice prior to making financial decisions.

Diffusion of best practices in the Australian Cotton Industry: Lessons learnt

Executive Summary

The widespread adoption of innovative farming practices and technologies has been fundamental to the competitive advantage for Australian Cotton growers has been. Many of these practices and technologies have emanated from strategic investment into Research and Development (R&D) and the collaborative culture within the industry. This has enabled growers to achieve a sustained yield advantage over rivals, as well as maintain a quality differentiation. Despite this, the industry faces a number of threats to both the short and long term competitive advantage. These include drought[1], competition from other cotton production regions internationally, and the risk that the yield growth which has sustained the industry could slow.

Whilst the Australian Cotton industry has been adroit in developing and diffusing value adding innovations, there remains scope for improvement. To that end this report:

a. Analyses what factors have been most salient in the adoption (or not) by growers of myBMP and energy management practices using diffusion of innovation (DOI) theory and the barriers framework.
b. Identifies what lessons can be learnt which may be useful in enabling industry participants to better identify value adding innovations, and enable their diffusion through the Australian cotton industry.
c. Presents a general adoption framework for innovation which is based on Innovation Diffusion Theory (IDT)

[1] Industry insiders recall the erosion of the Australian competitive position during the [2004-2009] drought, where reduced cotton production compelled international customers to seek alternative sources of cotton.

List of Abbreviations Used

Ag	Agriculture
Acctg	Accounting
BMP	Best Management Practice
CA	Cotton Australia
CRC	Cotton Cooperative Research Centre (Cotton CRC)
CRDC	Cotton Research & Development Corporation
DOI	Diffusion of Innovation
EMA	Environmental Management Accounting
IDT	Innovation Diffusion Theory
IS	Information SystemsMCS Management Control Systems
MAS	Management Accounting Systems
M&E	Monitoring and Evaluation
NCEA	National Centre for Engineering in Agriculture
NUE	Nitrogen Use Efficiency
R&D	Research & Development
RD&E	Research, Development & Extension
RDO	Regional Development Officer
STEEP	Socio-cultural, Technical, Ecological, Economic, Political (potential strategic threats)
UTS	University of Technology Sydney

Table of Contents

1. Introduction

1.1 Report Objective, Milestone and Performance Indicator

This report relates to the final component of the following objective and milestone for the project *Australian Cotton: Accounting for value chain sustainability and competitive advantage*:

Objective 3: To develop a method in which myBMP and improvements in its sustainability information content can be leveraged to develop improved competitive strategy in international cotton markets.

Milestone 3.3: Design an approach to enable the diffusion of the supply chain dashboard and myBMP to enable Cotton Australia to create competitive value.

This report forms the deliverable for the following performance indicator:

Performance Indicator 3.3: Protocols for innovation diffusion system at an industry level.

In the report *Strategy and Competitive Advantage: A Strategic Management System*, we identified that a key component of industry level competitive advantage for cotton growers is the widespread adoption of innovations and similar operational strategies across the industry[2]. To that end, this report:

a. Analyses what factors have been most salient in the adoption (or not) by growers of myBMP and energy management practices using diffusion of innovation (DOI) theory and the barriers framework
b. Identifies what lessons can be learnt which may be useful in enabling industry participants to better identify value adding innovations, and enable their diffusion through the Australian cotton industry

[2] This enables the emergence of a more coherent industry based competitive strategy (assuming the operational strategy translates into the competitive strategy. This also enables industry stakeholders to implement a broad based strategy without necessarily possessing the decision rights or management control systems which would be typically available for managers within firms. These issues are outlined in the report to the CRDC - *Strategy and Competitive Advantage: A Strategic Management System.*

c. Presents a general Adoption framework for innovation which is based on Innovation Diffusion Theory (IDT)

1.2 Report structure

In this report, we have used the cases of myBMP and energy management practices to draw inferences about how value enabling innovations can be diffused more effectively through the Australian cotton industry and what the barriers to innovation adoption may be. The report is structured into five sections: Section 2 comprises the myBMP case study; Section 3 contains the energy management practices case study; Section 4 presents key lessons learnt from both case studies; and, Section 5 presents a general adoption framework for innovation.

1.3 Theses contributing to this report

The project is primarily based on two honours theses completed at UTS, which were both designed as standalone projects. Their titles are:

- Lowe, P., 2012, Factors That Affect the Adoption of Management Accounting Systems in an Australian Agricultural Setting
- Soco, S., 2014, The Role of Management Accounting for the Control of Energy in an Agricultural Setting

Both of these will be made available to the CRDC.

This report is also informed by insights developed during the course of conducting the broader research project *Australian Cotton: Accounting for value chain sustainability and competitive advantage.*

2. Drivers of adoption and diffusion for myBMP

2.1 Introduction

We conducted a case study on the factors that affect the diffusion of myBMP within the Australian cotton growing industry. The context for this study was the relatively low uptake of the online myBMP system[3] compared to previous rate of adoption of the prior paper-based BMP system by Australian cotton growers. Significantly, growers' reluctance to engage with myBMP occurred despite investments by industry stakeholders to develop an online system with enhanced functionality as well as the potential for a 'myBMP' brand to underpin a sustainability-based competitive strategy for the industry.

Our objective was to explain why (or why not) myBMP is adopted by Australian cotton growers. This comprised two inter-related aims:

1. Inform factors which influence myBMP adoption and diffusion
2. Facilitate discussion and help improve myBMP diffusion

2.2 Factors affecting adoption/diffusion

To understand what factors influence the adoption of myBMP we conducted a review of innovation diffusion in the accounting, information system and agriculture literature. This review identified approximately 90 potential factors affecting the diffusion of innovation (these are listed in Appendix 3). For the purpose of this study, we focused on six of these factors[4] that capture characteristics of: the individual grower; the cotton growing organisation; the myBMP technology; and the cotton industry environment. These are summarised in Table 2.1 below.

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[3] Information provided by the CRDC showed that as of mid-2013, while approximately 300 growers were registered users of myBMP only approximately 30 were classified as 'active users'.

[4] The selection of these factors was based on the: 1) perceived relevance to myBMP/cotton; 2) significance across literatures; and 3) consistency of prior findings.

Factor	Characteristic of:	Description in the context of myBMP
Learned Helplessness	Individual grower	Grower's predisposition towards myBMP, typically based on past experiences and attitudes towards other innovations (e.g. BMP)
Perceived Resources	Grower's organisation	Grower's perceptions regarding the types, amounts and availability of resources required to adopt and engage with myBMP
Relative Advantage	myBMP technology	Grower's perceptions of the comparative benefits of using the system (e.g. include economic, social or informational benefits) relative to other available alternatives (e.g. other sources of information or on-farm management systems) or non-use.
Complexity	myBMP technology	Grower's perceptions regarding the ease of use of navigating the system; comprehending the information provided; and documenting practices within the system.
Consultants/ Agronomists/Cotton Seed Distributors	Cotton industry environment	Grower's perceptions of role of potential change agents within the cotton industry (that may advocate for adoption of innovation)
Social Network	Cotton industry environment	Grower's perceptions of the nature and influence of social networks (e.g. with other cotton growers) in encouraging the adoption of myBMP

Table 2.1 Factors affecting adoption/diffusion

2.3 Levels of adoption

The adoption of an innovation by organisations typically occurs to varying extents and stages ranging from 'not considered' to 'confirmation of the innovation-adoption decision'. In our analysis we treated the adoption of myBMP as a multi-stage process[5]. Through consultation with the CRDC we developed a simplified three-stage model of myBMP adoption, corresponding to the different levels of use of the myBMP system. The three levels are described in Table 2.2 below:

[5] This is in contrast to treating adoption as a binary decision (i.e. to adopt vs. not adopt). More detail on the way Lowe disaggregated the adoption decision is in Appendix 4.

Adoption stage	Description of growers in this stage
Non-use (or non-adoption)	Growers who : - Have never engaged with myBMP; - established an account and were introduced to myBMP, but had not returned to the system since doing so; or, - began the self-assessment process but after some time had ceased continuing with the process
Participation	Growers who : - commenced the self-assessment process, but have not completed it; or, - engaged with myBMP system on an ad-hoc basis as an information source concerning areas of interest
Accreditation	Growers who have attained myBMP accreditation

Table 2.2 Three stage model of myBMP adoption

2.4 Empirical approach

The empirical approach (see Appendix 1 for both the Lowe and Soco theses methods) consisted of two main phases: a preliminary background phase and the main data collection phase[6].

The aim of the preliminary phase was to gather information about the history, design and intended operation of the myBMP system itself. This involved collecting and analysing background material and industry reports about the myBMP system and interviewing industry stakeholders including members of Cotton Australia and the CRDC[7], myBMP system designers and managers, R&D extension officers and other relevant parties (e.g. researchers, consultants).

The aim of the main data collection phase was to gather and analyse the perceptions of growers about their use (or not) of myBMP. This involved conducting semi-structured interviews with 12

[6] In addition at the conclusion of the study the preliminary findings were reported and discussed with members of the Environmental Assessment Working Group in 2013.

[7] As the interview data used in the preliminary phase was collected as part of the broader project often these interviews did not focus exclusively on the issue of myBMP (interviewees also discussed other topics such as strategy, value chain, sustainability and R&D). In comparison, interviews conducted as part of the main data collection focused mainly on the issue of myBMP.

current growers[8]. We intentionally selected interviewees to represent a stratified sample of growers, representing different stages of myBMP adoption[9]. The 12 interviewees comprised of:

- 9 'Non-user' growers
- 2 'Participation' growers
- 1 Accredited grower

2.5 Key findings

Table 4.3 presents a summary of the empirical results regarding grower perceptions of the influence of the study's six factors on affecting their decisions about myBMP adoption.

	Learned Helplessness	Perceived Resources	Relative Advantage	Complexity	Consultants Agronomists CSD	Social Network
Non-users	Weak –	–	–	0	0	0
Participation	0	–	0 / +	Weak –	0	0
Accredited	0	0	+	Weak –	+	0

Table 2.3 Summary of Findings

NOTES: The signs in the above table designate the influence of the factor and the level of myBMP adoption at each stage: "–" designates a negative influence, "+ " designates a positive influence, " 0" designates no effect.

Highlights of these results include the following:

- **Most growers had positive prior experiences and association with BMP**

Overall, most respondents provided positive accounts of their experiences[10] in using the predecessor BMP system, indicating that 'learned helplessness' was not a significant factor. However, there was some concern that previously unrealised claims that BMP could enable farmers to achieve a market premium reduced the perceived value of myBMP as a marketing mechanism.

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[8] All these growers were located around Narrabri or Moree; most were highly experienced in growing cotton; they represented a mix of family and corporate farms, irrigated and dryland, and were of varying sizes (from 800-12,000 hectares).

[9] The number of growers in each stage corresponds approximately to the proportion of growers who are non-users, participants and accredited in the wider cotton grower population.

[10] For example, several recognised that the previous paper-based version (BMP) played a significant role in enabling Cotton Growers to maintain their social licence to operate during the period of public scrutiny over the use of pesticides.

- **Significant perceived resource requirements discouraged myBMP adoption**

All growers perceived myBMP to require substantial investments of time in adoption and use[11] . For non-users these time requirements were viewed as a major constraint to adoption, particularly for smaller organisations that did not have spare labour capacity to dedicate towards using myBMP.

- **Perceived relative advantage significant factor affecting decision to adopt or not**

Growers who engaged with the system perceived myBMP as offering benefits (e.g. industry-level social licence to operate, information resources, marketing/branding and risk management) that outweighed the resources required and that were superior to alternatives. In comparison, non-users generally discussed concerns over the lack of economic incentive and the availability of alternative sources of information, other regulatory requirements and the adequacy of their existing practices. We found some evidence that some of the best management practices which were highlighted in BMP have been institutionalised (grower is already doing them or is aware of them), reducing the perceived relative advantage of myBMP .

- **System complexity not significant factor**

Although growers raised concerns about some aspects of the myBMP system design (e.g. in interface design, internet connectivity issues), the complexity of the technology was not perceived to be a dominant factor affecting growers' eventual adoption decisions.

- **External agents do not advocate for myBMP adoption**

We found no evidence of external agents (e.g. consultants, agronomists or vendors) positively influencing the adoption of myBMP. This may be because often they provide alternative or substitute services.

- **Limited role of social network in promoting myBMP**

There is very limited promotion of myBMP through grower social networks, partially due to a deterioration of those networks. Growers contrasted the lack of social pressure to adopt with the influence of Area Wide Management groups in encouraging the uptake of BMP.

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[11] This included the time to attend workshops, to work through the system, to document, scan and upload supporting evidence for attainment of practices, to alter existing farm practices, to identify and extract the information from the system when used as an information source.

- **Emergent factors: grower consultation, communication and connection**

Three emergent factors (in addition to the original six factors) were raised by growers as affecting their adoption decisions. These factors all related to the broader connectedness between growers and myBMP stakeholders, including:

- Concerns about the compatibility in design to grower needs: The majority of grower respondents voiced concerns that a significant amount of resources (including grower levy funds) have been directed towards the development and design of the myBMP system, yet they the system is not perceived to provide discernible economic value to growers or industry. In addition many expressed concerns that the focus on formal documentation and standardisation of practices were incompatible with growers' informal approach to operating their farms and the necessary idiosyncrasy and variation in their practices to reflect local imperatives.
- The degree to which communication was targeted to non-user growers: Overall, growers perceived the marketing and communication of myBMP to be weak and ineffective in building awareness and stimulating adoption of the system. Partly this appeared driven by a more general change in the relation and communication patterns between growers and Cotton Australia (e.g. from high levels of face to face interaction, to increasing reliance on alternative channels, such as email and internet[12]). Significantly, there was a marked difference in the interaction patterns between users and non-users: non-users generally have very little interaction with Cotton Australia; whereas participants generally had much greater interaction with local extension officers and activities.
- The availability and timeliness of system support: With the exception of the respondents who are active participants, there is a general consensus that there is insufficient system support and contact with growers. Despite attempts to alter the myBMP design to become more intuitive to the user, growers expressed a preference for dedicated one-on-one contact (e.g. with local Research Development Officer or Regional Manager).

[12] This is partly attributable the impact on resource constraints on the maintenance of a face-to-face extension network, but also to growers increasing personal knowledge and experience which reduced their day-to-day need for information on cotton production.

3. Barriers to the adoption of energy management practices

3.1 Introduction

We conducted an exploratory case study to examine the factors which influence energy management practices in the Australian Cotton industry. The context for this study was the relatively low uptake of energy management practices despite their apparent advantage (we expand on this below). Our objective was:

1. Explore *how* energy is being managed by cotton growers

2. Explain *how* and *why* various factors influence energy management practices in an agricultural setting

Whilst there are a range of sources and uses for on-farm energy, we focus on the two main sources of energy for cotton production (Khabbaz 2010), namely:

- diesel (operation of machinery)
- nitrogen (crop nutrition)

3.2 myBMP and energy management practices

Extensive studies have analysed distinct farm processes and determined their related operational energy consumption and emissions. The energy consumption and GHG emissions of particular cotton farming activities throughout the supply chain has been investigated and it was determined that the most significant energy costs related to: logistics; cotton plantation; and diesel consumption for machinery (ICAC 2008; Jacobs 2006; Yilmaz, Akcaoz & Ozkan 2005).

There are significant differences between Australian Cotton farms' energy efficiency, suggesting that many farms are less efficient than they could be (Alcorn 2008; Baillie 2009; Khabbaz 2010; Pham et al. 2013). Specifically, Chen & Baillie (2009) finds that total energy inputs are strongly influenced by different application methods and management systems, leading to a discrepancy in energy consumption from 3.7 to 15.2 GJ/ha of primary energy (equivalent to 275 – 1404 kg CO_2 of greenhouse gas emissions per ha).

According to Baillie (2008; 2013), significant savings in energy can be derived through the implementation of energy assessments and audits. Audits and assessments are a crucial part in the energy and environmental management process, as they determine how efficiently energy is being used thus allowing for the identification of opportunities for significant cost savings and a reduction in GHG emissions (Baillie 2013; Chen, Kupke & Baillie 2008).

To that end, frameworks for the assessment of energy consumption on-farm have been developed in order to increase the awareness of growers of energy measurement and evaluation processes. For example, Chen & Baillie (2009) developed an energy calculator which estimates the energy usage and GHG emissions of the distinct farm processes for cotton production. A number of other energy and Greenhouse gas emission calculators for agriculture that have been developed both in Australia and overseas, including resources that assist growers in the management of nitrogen and fertilisers.[13]

The industry bodies in Australian cotton have advocated for the assessment and audit of on-farm energy use by growers, recommending the practice through numerous information outlets. For example, the Australian Cotton Production Manual (2014) details best practice regarding energy management, which includes the collation of energy data and the performing of energy assessments. It is summarised as follows (Sandell et al. 2014):

1. Level 1 Overview assessment: Farm energy performance is benchmarked over time and with other enterprises.
2. Level 2 Itemised assessment: Breaks down energy use into key farming processes and individual operations, identifying areas of high-energy use.
3. Level 3 Specific operation assessments: Measurements and data collection closely investigating a particular operation, identifying possible improvements in efficiency.

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[13] For example: 'EnergyCalc' is a web-based software tool developed by NCEA to assess on-farm energy use, costs and greenhouse gas emissions (CottonInfo 2014); United States Department of Agriculture (USDA) developed four separate energy calculators to estimate the energy uses in animal housing, irrigation, nitrogen, and tillage (Chen 2008); 'NutriLOGIC' is a cotton nutrient management support tool, which allows the data entry and analysis of nutrient inputs and is derived from the most up-to-date cotton nutrient research. (Rochester 2010).

The Australian Cotton Industry developed an industry-wide best practices network and support system, myBMP, to provide growers with a useful farm and environmental management program (Cotton Australia 2008). The aforementioned energy calculators and tools, as well as codified best practices have been incorporated into this management system, thus providing cotton farmers with a range of accessible tool to measure, assess, and improve their energy efficiency.

Despite the accessibility and benefits of energy assessments and audits, the number of growers measuring energy and practicing management is limited. The 2013 CRDC survey of cotton grower practices indicates the low level of engagement for these suggested energy management practices (Roth Rural 2013). The results from the survey are outlined in Table 3.1 below.

Energy management best practice (Source: myBMP.com.au)	**% Respondents in CRDC Survey of Cotton Growers (Roth Rural 2013)[14]**
Farm Total Energy Use is measured and/or benchmarked	11%
Total Energy Use is measured and/or benchmarked for individual operations	16%
A pump efficiency investigation has been undertaken	19%
Nitrogen Use Efficiency (NUE) is calculated. NUE is recorded and monitored over time.	13% of irrigated farms and 20% of dryland farms have NUE within the optimum range recommended by research
Plant Monitoring is undertaken during the season to assess nitrogen program	13% have a petiole/leaf nitrogen test conducted every season
Soil Tests are undertaken to assess nitrogen levels and fertiliser requirements	33% conduct soil tests every season

Table 3.1 Cotton grower engagement in energy management practices (Roth 2013)

Given that research has suggested that the adoption of energy management practices would be value adding, the relatively low level of adoption of these innovations begs the question as to why this is the case.

[14] Number of respondents for survey = 153 (21%). Survey responses covered approximately 23% of the 2012-13 irrigated cotton production area and 27% of the dry land cotton area.

3.3 Barriers Framework for explaining energy management practices

In this study we use Sorrell's (1990) Barriers framework[15] to explain why seemingly value adding energy efficiency projects (including energy management practices) have not had high levels of adoption. The value of the barriers framework is that it considers of a wide range of reasons for adoption / non adoption (See Appendix 5 for a comprehensive list of factors), each of which have been found relevant in various contexts. A key finding from this literature is that there is no "one size fits all" approach to enabling innovations to diffuse.

3.4 Empirical approach

The empirical approach consisted of two main stages. First, existing data and information relating to the Australian Cotton industry, Cotton Grower practices and other relevant information was reviewed to gain a preliminary understanding of energy management practices in the industry. Data included prior interviews[16], industry reports, manuals and surveys.

Second, more focused fieldwork was conducted trying to understand the perceptions of growers and other industry participants on issues identified in the first stage. This consisted of 13 semi-structured interviews conducted in the Namoi catchment area. The choice of interviewees was undertaken using the maximum variation sampling approach and consisted of:

- 6 growers (from a range of farm types and sizes)
- 2 accountants who specialize in agriculture (including cotton),
- 2 CRDC personnel
- 2 CRDC Regional Development Officers
- 1 Third party researcher

[15] A barrier to energy efficiency is defined by Sorrell et al. (2004), as a "postulated mechanism that inhibits a decision or behaviour that appears to be both energy and economically efficient". The lack of adoption of energy efficient practices has been widely recognised as the 'energy efficiency gap', where studies have reported the various reasons why environmental and cost effective measures have not been implemented (Hirst & Brown 1990; Sorrell, Mallet & Nye 2011; Trianni & Cagno 2012).

[16] Like the diffusion of myBMP study, the interview data used in the preliminary phase was collected as part of the broader project and often these interviews did not focus exclusively on the issue of energy management practices. In contrast, interviews conducted as part of the main data collection focused mainly on the issue of myBMP.

Interview data was analysed using NVivo 10 following a descriptive analytical approach; an exploratory case study was created to identify and explain how constructs (barriers) influence the adoption of energy management practices.

3.4 Key findings

The barriers framework was found to be a useful framework to describe and understand the factors, which influence the choice of energy management practices (for more detail on these energy management findings please see Appendix 6). However, there were notable differences in which factors were most relevant for different practices.

In the case of nitrogen management, the following elements from the barriers framework were found to be most relevant (see Table 3.2 for more detail):

a. Risk
b. Heterogeneity
c. Organisational Strategy

In the case of diesel management, the following elements from the barriers framework were found to be most relevant (see Table 3.2 for more detail):

a. Hidden Costs
b. Access to Capital
c. Risk
d. Heterogeneity
e. Bounded Rationality
f. Organisational Strategy
g. Values and Culture

Barrier	Description	Nitrogen	Diesel
Bounded Rationality	Reluctance to change and change the status quo. Limited attention paid to energy efficiency as attention is directed elsewhere (see Organisation Objectives and Priorities below)	Not key barrier	Energy management practices not integrated into routines - status quo is perceived as efficient
Heterogeneity	The results from research, other farms, and benchmarking was seen to be less applicable to the growers situation, largely due to differences in soil and other farm characteristics.	Importance of farm specific information	Available benchmarking information was seen as inconsistent and irrelevant for decision-making, as was information from energy audits
Lack of Capital	Lack of available capital for energy investments either due to competing objectives (see Organisation Objectives and Priorities below) or not available from capital providers	Not key barrier	Lack of available capital for energy efficiency investment
Organisation Objectives and Priorities	Yield maximization focus (key organizational priority) crowding out other priorities. In the mind of growers, energy efficiency was not explicitly (or tightly) related to yield or cost minimization strategy, in part due to perception of relatively low returns for improved efficiencies (compared to other activities such as soil improvement).	Energy efficiency not explicitly related to core business Relatively low returns for improved efficiencies	Energy efficiency not explicitly related to core business Relatively low returns for improved efficiencies
Risk	Key risks include: uncertainty of return on investment; uncertainty of business continuity; risk of financial loss	Financial losses from energy efficiency focused nitrogen management strategy (through loss of yield)	Uncertainty of return on investment and business continuity
Values and Culture	Lack of culture supporting energy efficiency focus, where yield was viewed as king. Energy management practices not integrated into routines	Not key barrier	Lack of culture supporting energy efficiency focus and data collection
Hidden Costs	Lack of time and labor devoted to energy efficiency. Difficulties and costs in obtaining information. Lack of easily accessible metering and recording mechanisms	Not key barrier	Difficulties and costs associated with energy efficiency practices

Table 3.2 Summary of key barriers to adoption of energy management practices

4. Lessons learnt and implications

Based on the two case studies presented in Sections 2 and 3, there are three key, interrelated lessons regarding the diffusion of myBMP and energy management practices within the Australian cotton industry.

Lesson 1: The myBMP system appears to have multiple objectives which induce tradeoffs in the design, positioning and use of the system

MyBMP appears to represent many things to many people. These different 'visions' of myBMP include:

- Accreditation mechanism used to measure and audit current cotton growing practices.
- Marketing or branding device envisioned (either to attract a premium for Australian cotton in external cotton markets or to brand the sustainability credentials of the Australian industry to maintain the social licence to operate domestically).
- Risk management tool used by growers to ensure their practices comply with current legislative and regulatory requirements.
- Centralised information platform to enable growers to access relevant, up-to-date, scientifically verified information about current best practice.
- A channel to disseminate findings from industry-funded R&D projects (and demonstrate 'industry engagement' to funders)

Significantly, each of these different visions of myBMP entail substantial variation in the objectives of the system, which in turn create different requirements in how the system should be designed, positioned and used. Furthermore, they entail differences in how the system is envisioned to be used by growers over time.[17]

Key implication: Develop consensus on the objectives of myBMP amongst relevant stakeholders, ensuring an alignment with the strategic priorities of growers.

Once these objectives are determined, they need to be translated into a consistent set of strategies regarding myBMP's ongoing design and maintenance, communication, grower engagement, systems support and wider integration with other activities and practices within the cotton industry.

[17] For example, if myBMP is used as an accreditation mechanism one would expect growers to engage intensively with the system during a distinct single period of time until accreditation is achieved; in comparison, if myBMP is used a centralised information platform one would expect growers to engage with the system intermittently in perpetuity.

Lesson 2: The value proposition of some 'best practices' is not clear to growers

In both case studies, a latent issue that prevented the diffusion of myBMP and energy management practices was a lack of clarity, from the growers' perspective, of the 'value proposition' of both these types of innovation. This was reflected in a number of observations:

- Confusion about the objectives, purpose and intent of proposed innovations
- Cynicism of stated benefits
- Perceived lack of economic incentives for adoption (i.e. lack of 'business case')
- Perceived misalignment between individual growers' own business strategies and suggested 'best practice'

Key implications: Develop and communicate the value proposition of myBMP and the energy management practices to growers.

A process needs to be implemented to independently review the 'value proposition' for growers to engage with the myBMP system, with a view to remove non-value add innovations and practices.[18] Future suggestions of 'best practice' should be accompanied with a business case, to ensure that only value adding practices are incorporated. In addition, where the value of 'best practices' is not discernible to growers, further research and or an amended communication strategy is warranted.

Lesson 3: Multiple factors influence the diffusion of different innovations

Both case studies reveal that there are a range of different factors which influence grower adoption decisions. Therefore a one-size-fits-all approach to the diffusion of best practices across the cotton industry is unlikely to succeed.

Key Implication: Referral to a general adoption framework to develop formal diffusion strategies.

Industry stakeholders interested in diffusing a new innovation, or seeking to understand why a given innovation has not been diffused can start from a general adoption framework for innovation based on Innovation Diffusion Theory (IDT). Then this can be adapted or modified for the type of innovation, the stage of adoption and implementation and the category of adopter. This will be laid out in the following section. This general model can be used as the basis of the extension strategy for the CRDC.

[18] This could involve a formal assessment evaluating existing elements of myBMP, based on the collection of useful data on grower practices, inputs and outputs (including yield, quality and price) to enable rigorous evaluation of how differences in practice are linked to differences in productivity. Another possibility is to gather data on grower pilots where an innovation has been trialled on a farm on a commercial scale, and make this information accessible to relevant stakeholders.

5. Protocols for innovation diffusion system at an industry level

In this section we present a general adoption framework for innovation which is based on Innovation Diffusion Theory (IDT). This framework is comprised of four dimensions to consider when developing a diffusion strategy for a specific innovation: general factors affecting adoption; types of innovation; categories of adopters; and stages of adoption.

5.1 Innovation Diffusion Theory

Innovation diffusion theory (IDT) was developed by E.M. Rogers in 1962 who defines diffusion as "the process by which an innovation is communicated through certain channels over time among members of a social system" Rogers 1995, p. 10[19].

5.2 General factors that influence innovation adoption

In general, there are five overarching factors that influence adoption of innovation. These factors are described in Table 5.1 below.[20]

Factor	Definition
Relative Advantage	The degree to which an innovation is seen as better than the idea, program, or product it replaces.
Compatibility	How consistent the innovation is with the values, experiences, and needs of the potential adopters.
Complexity	How difficult the innovation is to understand and/or use.
Trialability	The extent to which the innovation can be tested or experimented with before a commitment to adopt is made.
Observability	The extent to which the innovation provides tangible results.

Table 5.1 General factors that influence adoption

As illustrated in the two empirical studies, the role of these general factors in relation to individual innovations varies. The salience of factors in influencing the adoption of a specific innovation by a particular set of organisations will vary due to:

- The type of innovation
- The category of adopter
- The stage of adoption

[19] Innovation Diffusion literature exists across three major disciplines, Agriculture, Accounting and Information Systems, all of which has been reviewed in the course of this study.
[20] This section presents five general factors which apply broadly to innovation adoption in a wide range of contexts. Appendix 3 provides a list of over 90 factors that may apply in more specific contexts (as discussed in Section 2 and 3).

When developing a diffusion strategy for a specific innovation, the relevant stakeholders should consider each of these three elements.

5.3 Types of innovations

Innovation is not just about technical innovations. In general, we can draw a distinction between at least three different types of innovation, as presented in Table 5.2.

Type	Innovation	Industry example
1	Product innovation	New cotton varieties; round bale picker
2	Operational process innovation	Integrated Pest Management; Irrigation strategy
3	Administrative process innovations	myBMP

Table 5.2 General factors that influence adoption

As each innovation is, by definition, unique, it is difficult to prescribe a universal model of innovation diffusion. The adoption of different innovation types is likely to be driven by different combinations of factors. When developing a diffusion strategy for a specific innovation, the idiosyncratic nature of the type of innovation needs to be taken into account

5.4 Categories of adopters

Researchers have found that some segments of the targeted population are more apt to adopt the innovation than others and have defined five adopter categorisations as depicted in Figure 5.1.

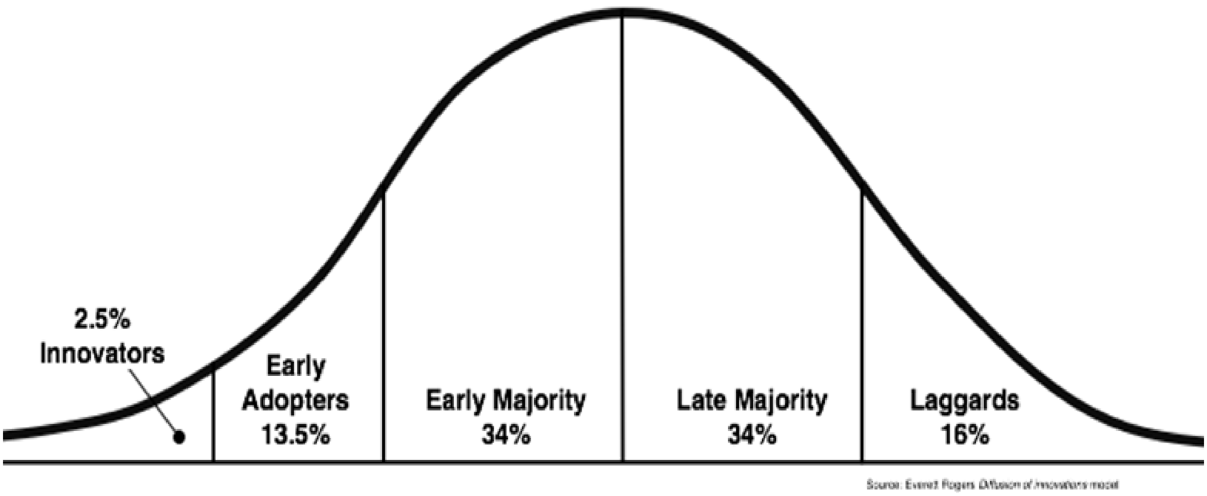

Figure 5.1 Roger's Bell Curve of Adopter Groups

Stakeholders should adapt their diffusion strategy to suit each category of adopter. These implications are summarised in Table 5.3.

Category	Definition	Implication for diffusion strategy
Innovators	People who want to be the first to try the innovation. They are venturesome and willing to take risks.	Little strategy is required to persuade this group to adopt the innovation.
Early Adopters	People who are already aware of the need to change and need little convincing to adopt the innovation.	Providing implementation manuals and keeping them informed about the implementation process encourages their adoption.
Early Majority	Happy to adopt ahead of the pack as long as they are assured that it works.	They are motivated by hearing about success stories and evidence of the innovation's effectiveness.
Late Majority	Resistant to change, and will only adopt an innovation after being assured that it has been tested and proved to be effective by many other users.	They are motivated by evidence of relative advantage and widespread adoption rates.
Laggards	Very resistant to changing without some compulsion such as statistics, horror stories, peer pressure.	Potentially very costly to motivate, without resorting to regulation and compliance.

Table 5.3 Categories of adopters

5.5 Stages of adoption

Consideration of the decision to adopt an innovation requires more than simply categorising this as a binary decision to adopt or not adopt. This is manifest in the extent to which an innovation is implemented within an organisation and the impact of factors that influence adoption.

This distinction is defined by Brown (2000) in developing the stages of the Activity Based Costing (ABC) adoption process:

> *"Adoption is about the decision to accept or formally approve the innovation. Implementation, however, relates to the process of carrying out this decision, putting it into effect" , p. 36.*

Five common stages by which an entity adopts an innovation (and diffusion is accomplished[21]) have been identified, which we present in Table 5.4 below:

[21] The extent of *diffusion* is measured by the *percentage of adoption* within the social system being observed. Therefore, the stages of adoption and implementation often occur simultaneously.

Adoption stage	Definition
Not considered	The potential adopting entity has not considered the need for the innovation. They may not even be aware they have the problem it is intended to resolve. The degree to which an innovation is seen as better than the idea, program, or product it replaces is a key factor.
Initiation/evaluation (knowledge persuasion)	Potential adopters learn what the innovation is and how it works. They form a negative or positive impression as to the benefit it can bring them. This is often the point of first knowledge and / or persuasion.
Decision (adopt or reject)	Adopt or reject: after reviewing the applicability of relevant business drivers, the entity resolves whether to proceed with adopting the innovation.
Increasing levels of innovation use / implementation	An implementation process appropriate to the entity/innovation is developed. This should result in the adopting organisation being properly prepared for the change it is intended to adopt. The degree of adoption reflects the success of the implementation.
Confirmation of the innovation-adoption decision (continue, modify, or discontinue use)	If the users continue to use the innovation, it can be confirmed that it has been adopted. If the innovation falls into disuse, the implementation has failed and the innovation has not been adopted. The practical end result that there is no confirmation of the adoption of the innovation.

Table 5.4 Common stages of innovation adoption (based on Rogers 1995 and Krumwiede 1998)

Successful progression through each stage in the adoption (decision) process is a reflection of increasing commitment to an innovation which is interpreted as a measure of *success* via the extent of *innovation usage* (Brown 2000; Brown, Booth & Giacobbe 2004; Feder, Just & Zilberman 1985; Frambach & Schillewaert 2002; Krumwiede 1998; Kwon & Zmud 1987; Pannell et al. 2006; Prescott & Conger 1995; Rogers 1995; Ryan & Gross 1943).

Stakeholders can use the stages of adoption as a means to monitor and evaluate the progress of a diffusion strategy. This can be accomplished by tracking individual grower adoption decisions (at each stage), which when aggregated provides a more complete diagnostic of the level of adoption and diffusion within the industry. In addition, stakeholders can identify the grower concerns that may present at different stages of adoption, and design stage-targeted strategies and initiatives.

5.6 Summary

In considering the above ideas, factors of adoption will have an impact on the decision to adopt and implement an innovation. These factors may have different effects depending on the type of innovation, the category of adopter and the stages of adoption. As firms successively adopt an innovation, it becomes diffused throughout a broader population.

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Appendices

Appendix 1: Sample and data sources

This is a summary of the research methods and data used in the two theses that form the basis of this report.

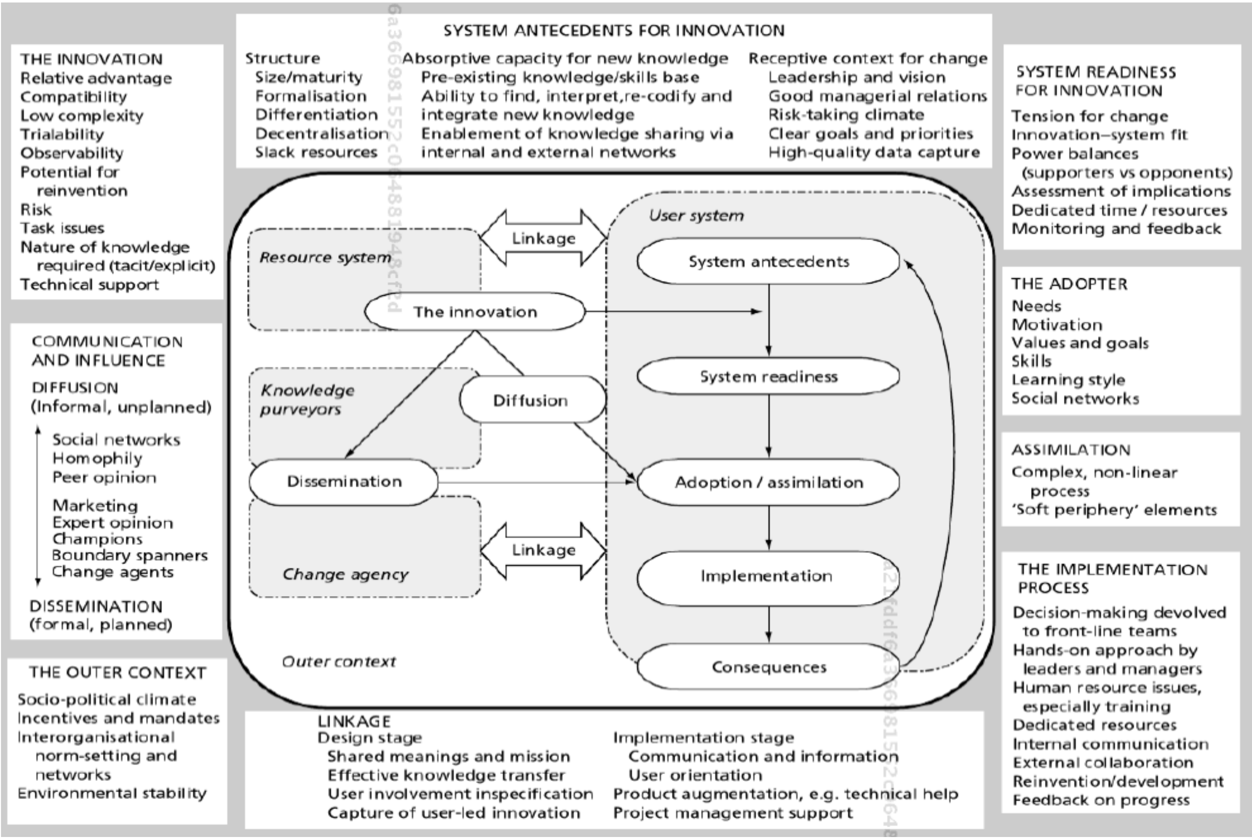
Candidate	Theory Motivation	Research Method	Data	Level
Lowe	Existing (MAS) DOI literature focuses on Manufacturing, IS, Finance – this research seeks to fill the gap relating to Agriculture	Adoption process formulated by a review of DOI Literature formed the conceptual framework. A case study was then created as an empirical model to identify salient factors of adoption /non-adoption.	Archival reports, pre-existing interviews Structured and semi-structured interviews with 12 Growers (max variation sampling approach) 5 Semi-structured interviews with Cotton Industry parties. Interview data was analysed using NVivo 10	Honours
Soco	Using the barriers framework to inform the analysis, this research seeks to: i) Address the gaps in the literature ii) Explain the factors influencing the practice of EMA in an agricultural setting.	Following a descriptive analytical approach, an exploratory case study was created to: i) theorise how constructs which influence the conduct of EMA for energy have developed ii) build upon existing notions of practice.	Relevant literature (industry reports, manuals, surveys,) 13 semi-structured interviews , (6 growers, accountants, CRDC personnel/RDOs, max variation sampling approach) on farm energy management practices. Interview data was analysed using NVivo 10	Honours

Appendix 2: Summary of Innovation Diffusion Theory

The most comprehensive articulation of this is by Greenhalgh et al. (2005), whom consolidated much of this vast IDT literature, as illustrated in the Figure below. This illustration situates innovation in the realm of systems implementation. The external drivers for change and normalisation are considered and aspects of the innovation and the adopter are analysed. Major antecedents for innovation within the system are identified in terms of how it is structured, what the capacity for new knowledge is and how receptive its context is for change. Key characteristics of system readiness for innovation and the implementation process are listed.

Importantly, the interface between the end user community and the designers and change managers is highlighted as “Linkages” at two different stages: the design stage - to involve the user in the specification of the innovation; and the implementation stage when it is critical to keep the user community informed and orientated.

This communication and influence effort is further amplified in a continuum between dissemination, depicted as the formal planned activities of change agents, subject matter experts and champions, and diffusion, where more informal influence occurs, directed by social networks and like-minded peer groups.



Conceptual model for the spread and sustainability of innovations (Source: Greenhalgh et al., 2005, p. 201)

Appendix 3: List of factors previous research has found to be salient in IDT

Category	Factor	Comment	Literature Source
Individual	Job tenure	The length of service and experience of the job-holder	Ag, Acctg, IS
	Age		Ag
	Self-image and brand loyalty		Ag
	Gender		IS
	Education		Ag
	Role involvement		Ag, Acctg, IS
	Cosmopolitanism	Contact with the outside world	IS
	Disposition to change		Ag, Acctg
	Informal support		Ag, Acctg, IS
	Critical mass	The point where enough individuals have adopted an innovation that the majority of other users accept its utility and adopt it themselves	IS
	Unit professionally oriented		IS
	Risk aversion/perception and attitude to risk (attitude)		Ag
	Learned helplessness (attitude)	A predisposing aspect of an individual's personality which drives them to resist adoption. Likely due to past experience - a perception of a lack of personal control and ability to influence individual circumstances	Ag
	Computer self-efficacy		Ag, IS
	Behavioural intention (individual adoption)		IS
	Outcome expectations (performance) (Individual adoption)		Ag, IS
	Outcome expectations (personal) (individual adoption)		IS
	Attitude towards conservation /Awareness and concern for the issue (e.g. soil erosion)		Ag
Structural	Top management support		Acctg, IS
	Top management characteristics		IS
	Middle management support		IS
	Champion		Acctg, IS
	Specialisation		Acctg, IS
	Centralisation (part of		Acctg, IS

	organisation structure)		
	Formalisation		Acctg, IS
	Vertical differentiation (part of organisation structure)		Acctg
	Administrative intensity		IS
	Size		Ag, Acctg, IS
	Informal network		Acctg, IS
	User support (Individual adoption)		IS
	Training and investment		Ag, Acctg, IS
	Managerial training		IS
	Experience		IS
	Fit		IS
	Organisational innovativeness or strategic posture		Acctg
	Culture of adopting unit		Acctg
	Institutional credit and off-farm income	Funding obtained from savings, bank loans, capital markets and other external sources	Ag
	Perceived resources	Resources (financial or otherwise) believed to be available to facilitate adoption	Ag
	Professionalism of the IS unit		IS
	Quality orientation		IS
	Facilitating conditions (individual adoption)		IS
	Environmental instability		IS
	Career ladder		IS
	IS maturity		IS
	IS department size		IS
	Cost		Ag, IS
Technological	**Complexity**	The ease of use of navigating the innovation and the comprehensibility of information provided about it	Ag, Acctg, IS, Greenhalgh
	Compatibility	Perception that the innovation satisfies the adopters' needs or produce value for the growers or industry	Ag, Acctg, IS, Greenhalgh
	IT quality		Acctg, IS
	Relative advantage	The comparative benefits adopters perceive through the use (or not) the innovation	Ag, Acctg, IS, Greenhalgh
	Interpretative viability		Acctg
	Accuracy		Acctg
	Decision usefulness		Ag, Acctg
	Relevance to decision making		Acctg, IS
	Dominance of overhead		Acctg

	Product line complexity		Acctg
	Product diversity		Acctg
	Trialability	The extent to which the innovation can be tested or experimented with before a commitment to adopt is made.	Ag, Acctg, IS, Greenhalgh
	Observability	The extent to which the innovation provides tangible results	Ag, Acctg, IS, Greenhalgh
	Potential for reinvention	The extent the innovation can be modified by the user in the process of adoption	Greenhalgh
	Riskiness	The amount of risk associated with adopting an innovation	Greenhalgh
	Uncertainty		Ag, Acctg
	Decreasing price		IS
	Large new application portfolio		IS
	Match between the perceived benefits of an innovation and actuality		Ag
	Perceived voluntariness	Extent to which use of the innovation is perceived to be at the potential user's free will	Ag, IS
	Land tenure		Ag
Task Related	Task uncertainty		Acctg, IS
	Task-technology compatibility		IS
	Autonomy		Acctg, IS
	Variety		IS
	Training		IS
	TQM implementation	Total Quality Management	IS
	Lean production	A Japanese approach to management that focuses on cutting out waste, whilst ensuring quality e.g. Just in Time	IS
	Job shop	Typically small manufacturing systems that handle custom/bespoke processes	IS
Environmental	Heterogeneity	Diversity	IS
	Uncertainty		Acctg, IS
	Competition		Ag, Acctg, IS
	Inter-organisational dependence		IS
	External communication	Degree of involvement in extra-organisational professional activities	Ag, Acctg, IS
	Consultants	Extension agents, consultants, agronomists, and cotton seed distributors who may act as change agents	Ag, Acctg

	Government policies/regulation		Ag
	Distance between diffuser and adopter		Acctg
	Social network	Local, intra-firm, inter-firm or public networks that can facilitate adopt/not adopt decisions	Ag, Acctg, Greenhalgh
	Opinion leaders	Those perceived as having particular influence, positive or negative, on the beliefs and actions of their colleagues	Ag
	Social values and norms		Ag
	Quality of support		Ag
	External pressure		IS
	Customer support		IS
	Targeting and communication efforts of suppliers		Acctg
	Risk reduction via marketing activities		Acctg
	Other firms adopting/network externalities		Ag, Acctg, IS
Behavioural	Bounded rationality	Instead of being based on perfect information, decisions are made by rule of thumb.	Barrier Theory
	Form of information	Research has shown that the form of information is critical. Information should be specific, vivid, simple, and personal to increase its chances of being accepted.	Barrier Theory
	Credibility and trust	The information source should be credible and trustworthy in order to successfully deliver information regarding energy efficiency measures. Where these factors are lacking inefficient choices may result.	Barrier Theory
	Inertia	Individuals who are opponents to change within an organisation may result in overlooking energy efficiency measures that are cost--efficient.	Barrier Theory
	Values	Efficiency improvements are most likely to be successful if there are individuals with real ambition, preferably represented by a key individual within the top management.	Barrier Theory

Organisational	Power	Low status of energy management may lead to lower priority of energy issues within organisations.	Barrier Theory
	Culture	Organisations may encourage energy efficiency investments by developing a culture characterised by environmental values.	Barrier Theory
Economic non-market failure	Heterogeneity	A technology or measure may be cost-efficient in general, but not in all cases.	Barrier Theory
	Hidden costs	Examples of hidden costs are overhead costs, cost of collecting and analyzing information, production disruptions, inconvenience, etc.	Barrier Theory
	Access to capital	Limited access to capital may prevent energy efficiency measures from being implemented.	Barrier Theory
	Risk	Risk aversion may be the reason why energy efficiency measures are constrained by short payback criteria.	Barrier Theory, Greenhalgh
Economic market failure	Imperfect information	Lack of information may lead to cost-effective energy efficiency opportunities being missed.	Barrier Theory
	Split incentives	If a person or department cannot gain from energy efficiency investments it is likely that implementation will be of less interest.	Barrier Theory
	Adverse selection	If suppliers know more about the energy performance of goods than purchasers, the purchasers may select goods on the basis of visible aspects such as price.	Barrier Theory
	Principal-agent relationships	Strict monitoring and control by the principal, since he or she cannot see that what the agent is doing, may result in energy efficiency measures being ignored.	Barrier Theory
Design stage linkage	Shared meaning and mission		Greenhalgh
	Effective knowledge transfer		Greenhalgh
	User involvement in specification		Greenhalgh
	Capture of user-led innovation		Greenhalgh

Implementation stage linkage	Communication and information		Greenhalgh
	User orientation		Greenhalgh
Structure	Size and maturity		Greenhalgh
	Level of formalisation	Emphasis on following rules and procedures in conducting organisational activities	Greenhalgh
	Functional differentiation	Extent to which the entity is divided into different units	Greenhalgh
	Centralisation	Extent to which decision-making autonomy is dispersed or concentrated within organisation	Greenhalgh
	Slack resources	Resources available beyond the minimal requirement to maintain operations	Greenhalgh
Users' new knowledge absorptive capacity	Pre-existing knowledge/skills base		Greenhalgh
	Ability to find, interpret and integrate new knowledge		Greenhalgh
	Enablement of knowledge sharing via internal and external networks		Greenhalgh
Change-receptive context	Leadership and vision		Greenhalgh
	Good managerial relations		Greenhalgh
	Risk-taking climate		Greenhalgh
	Clear goals and priorities		Greenhalgh
	High quality data capture		Greenhalgh
System readiness for innovation	Tension for change		Greenhalgh
	Innovation-system fit		Greenhalgh
	Power balances	Between supporters and opponents	Greenhalgh
	Assessment of implications		Greenhalgh
	Dedicated time and resources		Greenhalgh
	Monitoring and feedback		Greenhalgh
Communication and influence	Homophily	The extent of similarity, or shared norms, between two or more individuals who interact re belief, education, social status etc.	Greenhalgh
	Peer opinion		Greenhalgh
	Marketing		Greenhalgh
	Expert opinion		Greenhalgh

	Champions	Often sympathetic, respected, high-profile internal entreprenuers who sponsor or advocate for the innovation.	Greenhalgh
	Boundary spanners	People of influence, with ties across organizational and other boundaries	Greenhalgh
	Change agents	An individual who influences clients' innovation decisions in a direction deemed desirable by a change agency	Greenhalgh
Outer Context	Socio-political climate		Greenhalgh
	Incentives and mandates		Greenhalgh
	Interorganisational norm-setting and networks		Greenhalgh
	Environmental stability		Greenhalgh

Legend

(a) The symbols displayed in the tables above indicate the relationship found in each of the studies reviewed and are as follows; + is positive; – negative; 0 means no relationship was found

(b) **Agriculture Literature** relates to those studies which explore adoption within an agriculture setting. The letters and corresponding relationship are placed in line with the relevant factors examined in the particular study, with each letter corresponding the relevant paper as follows; **F.** Feder, Just and Zilberman (1985); **M.** Mackrell, Kerr and von Hellens (2009); **G.** Guerin and Guerin (1994); **P.** Pannell et al. (2006); **KB** Knowler and Bradshaw (2007); **FU.** Feder and Umali (1993); **A.** Aubert, Schroeder and Grimaudo (2012); **L** Lobel (1987); **MA.** Marra, Pannell and Abadi Ghadim (2003); **S.** Sneddon, Soutar and Mazzarol (2011); **SWC.** Saint & Coward 1977

(c) **Accounting Literature** relates to those studies which explore adoption within an agriculture setting. The letters and corresponding relationship are placed in line with the relevant factors examined in the particular study, with each letter corresponding the relevant paper as follows; **A.** Anderson (1995); **BG.** Booth and Giacobbe (1998); **B.** Bjørnenak (1997); **K.** Krumwiede (1998); **BN.** Brown (2000) and Brown, Booth and Giacobbe (2004)[22]; **AB.** Ax and Bjørnenak (2005); **ABJ.** Ax and Bjørnenak (2007); **BHR.** Baird, Harrison and Reeve (2004); **BM.** Bol and Moers (2010); **F.** Frambach and Schillewaert (2002); **G.** Gosselin (1997)

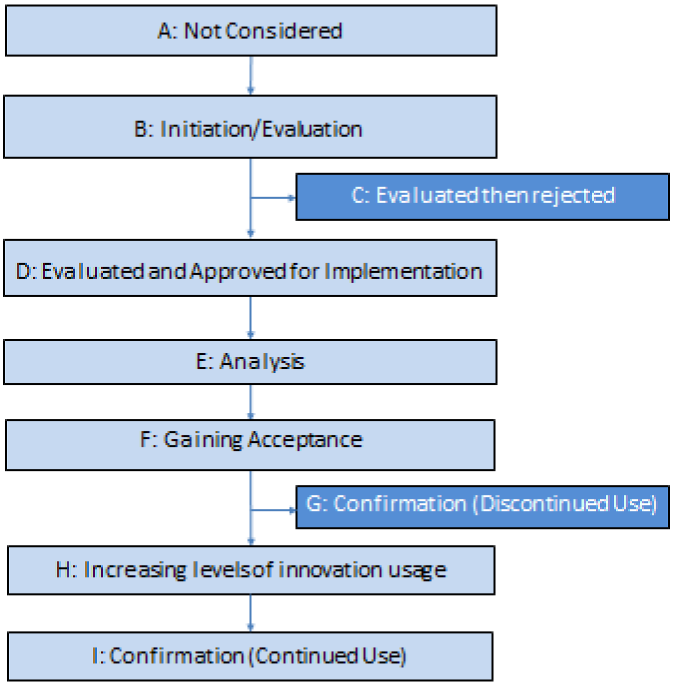
(d) **I.S. Literature** relates to those studies which explore adoption within an agriculture setting. The letters and corresponding relationship are placed in line with the relevant factors examined in the particular study, with each letter corresponding the relevant paper as follows; **W.** Wolfe (1994); **P.** Prescott and Conger (1995); **S.** Swanson (1994); **K.** Kwon and Zmud (1987); **J.** Jeyaraj, Rottman and Lacity (2006); **CZ.** Cooper and Zmud (1990)

(e) **This Study** identifies the factors which will be examined in this study and is market with an X. The expected relationship in theorised as part of Section 2.3.2 Key Relevant Factors of Influence

[22] Top management support, internal champion support and organisational size influenced initial interest, whilst champion support influenced adoption

Appendix 4: Stages of adoption in myBMP case study

Lowe (2012) used the following 9 stage adoption model to focus her study of myBMP adoption decisions.



Stages of adoption utilised by Lowe (2012)

This shows two effective decision points where the innovation is either consciously evaluated as not being appropriate for adoption or, after an attempt to implement it, the innovation has not been not been taken up by its intended user community and the implementation can be deemed a failure.

Depending on the nature and scale of the implementation, Stage E: Analysis can refer to:

- review of current procedures
- mapping current and new requirements against the innovation
- determining if any modifications to the innovation are required
- assessing data impacts, training needs, implementation risks
- preparing the roll out plans, including support arrangements
- updating operational policies and procedures

Stage F: Gaining Acceptance will require

- clear communication within the adopting organisation as to:
    - why the change is necessary and

- how it will be achieved.

Again, dependent on the type of innovation, it may also need:

- committed leadership
- appropriate allocation of resources
- sufficient time scheduled for testing and training
- accessible post-implementation support

Appendix 5: Barriers framework (Sorrell 2000)

Category	Factor	Explanation
Behavioural	Bounded rationality	Instead of being based on perfect information, decisions are made by rule of thumb.
	Form of information	Research has shown that the form of information is critical. Information should be specific, vivid, simple, and personal to increase its chances of being accepted.
	Credibility and trust	The information source should be credible and trustworthy in order to successfully deliver information regarding energy efficiency measures. Where these factors are lacking inefficient choices may result.
	Inertia	Individuals within an organisation who are opposed to change may result in overlooking energy efficiency measures that are cost-efficient.
	Values	Efficiency improvements are most likely to be successful if there are individuals with real ambition, preferably represented by a key individual within the top management.
Organisational	Power	Low status of energy management may lead to lower priority of energy issues within organisations.
	Culture	Organisations may encourage energy efficiency investments by developing a culture characterised by environmental values.
Economic non-market failure	Heterogeneity	A technology or measure may be cost-efficient in general, but not in all cases.
	Hidden costs	Examples of hidden costs are overhead costs, cost of collecting and analyzing information, production disruptions, inconvenience, etc.
	Access to capital	Limited access to capital may prevent energy efficiency measures from being implemented.
	Risk	Risk aversion may be the reason why energy efficiency measures are constrained by short payback criteria.
Economic market failure	Imperfect information	Lack of information may lead to cost-effective energy efficiency opportunities being missed.
	Split incentives	If a person or department cannot gain from energy efficiency investments (even when in would benefit the entity), it is likely that

Category	Factor	Explanation
		implementation will be of less interest.
	Adverse selection	If suppliers know more about the energy performance of goods than purchasers, the purchasers may select goods on the basis of visible aspects such as price.
	Principal-agent relationships	Strict monitoring and control by the principal, since he or she cannot see that what the agent is doing, may result in energy efficiency measures being ignored.

Appendix 6: Energy management practices findings

The primary objectives of the organisation was a significant consideration in the choice for energy management practices, as growers prioritised the activities that contributed to the improvement of yield, while energy efficiency activities were of relatively less importance.

Hence, energy management practices varied significantly across the two sources (i.e. nitrogen optimisation being prioritised over cost efficiencies from diesel management).

On the one hand, diesel was seen as a cost of doing business, with little attention paid to optimising operations on a regular basis, with few 'conventional' records kept or used. When equipment either broke down or needed replacement, growers performed efficiency evaluations at the time and relied on the reports and advice of technical experts and other growers. Optimisation of existing infrastructure was perceived to be a low value proposition, with a common view that key elements of their infrastructure were currently efficient.

There was evidence of growers engaging in the following practices in an ad-hoc manner: measurement of diesel; benchmarking; audits and assessments; efficiency evaluations (i.e. pump efficiency). This suggests that whilst growers were engaging in some key energy management practices, they were not acting systematically.

On the other hand, nitrogen application rates were carefully monitored so as to maximise yield. Growers conduct numerous farm trials, testing different application timing and rates. A control cycle consisted of:

i. Target development; target yield is formulated considering the expected water allocation, rainfall, field and market conditions.

ii. Nitrogen strategy formation and budgeting; nitrogen application rates and timing are determined and informed by soil tests, nitrogen inventory accounts, trial data etc.

iii. Monitoring and control; crop performance is monitored and assessed, and included amendments to nitrogen strategy

iv. Evaluation of crop and nitrogen performance, which informed the following cycle

Highlights of these results include the following:

- **Limited use of energy management practices for diesel management**

Many growers do not actively measure, benchmark or assess the energy efficiency of pumps and machinery. They collect simple records of diesel consumption or none at all. Growers can also employ accountants that are able to perform benchmarking activities for the analysis of farm operations. This is despite research consistently demonstrating the benefits of accounting for energy inputs and their related activities, rather than the costs themselves.

- **Little reliance on audits and pump investigations**

Even when attempted, the growers perceived the information to be not relevant or useful for decision-making. This perception from growers for the lack of benefit of energy audits and assessments conflicts with the case studies by Baillie (2008) and Baillie (2013), which report significant costs savings in energy.

- **Efficiency evaluations are conducted intermittently on an ad hoc basis**

Growers undertook ad hoc diesel-related energy efficiency evaluations and typically only during the occurrence of breakdowns, where they then relied on the information provided to them by suppliers and other growers when deliberating the asset replacement decision.

- **Soil nitrogen inventory accounts were widely maintained**

It was found that growers recorded and measured soil nitrogen inventory accounts, which formed the basis of nitrogen budgets and strategies. These outline the expected rates and targets for the season and are regularly evaluated, incorporating the advice of agronomists, prior experiences and trial data.

- **Nitrogen use is monitored and controlled with a focus on yield (as compared to energy efficiency)**

Growers utilise agronomists and visual inspections to assess and provide recommendations for the improved efficacy of nitrogen plans and strategies.

- **Little reliance on leaf tests and technical data**

Research and industry bodies advocate the use of petiole tests and analysis for the improved monitoring and decision making of nitrogen management. Respondents expressed the lack of relevance and usefulness for these tools and models as reasons for their limited take-up (keeping in mind that growers had sampled these practices so were not uninformed).