TECHNICAL REPORT

ACCELERATING PRECISION AGRICULTURE TO DECISION AGRICULTURE

Enabling digital agriculture in Australia

This Project is supported by funding from the Rural R&D for Profit Program

Australian Government
Department of Agriculture and Water Resources

Australian Farm Institute

Analysis of the economic benefit and strategies for delivery of digital agriculture in Australia.

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Australian Government
Cotton Research and Development Corporation

FRDC
awi Australian Wool Innovation Limited
AMPC
Australian eggs
Australian Pork
LiveCorp
GRDC Grains Research & Development Corporation
Horticulture Innovation Australia
Dairy Australia
AgriFutures Australia
Forest & Wood Products Australia
sra Sugar Research Australia
Wine Australia
mla Meat & Livestock Australia

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Table of Contents

Table of Contents (continued)

Abbreviations

Acronym	Meaning
ABARES	Australian Bureau of Agricultural and Resource and Economics Sciences
ABS	Australian Bureau of Statistics
ACCC	Australian Competition and Consumer Commission and Productivity Commission
ACFR	Australian Centre for Field Robotics
AECL	Australian Egg Corporation Limited
AFMA	Australian Fisheries Management Authority
AGWA	Australian Grape and Wine Authority
AMPC	Australian Meat Processor Corporation
APL	Australian Pork Limited
ARC	Australian Research Council
AWI	Australian Wool Innovation Limited
BCG	Boston Consulting Group
CAD	Computer Aided Design
CIE	Centre for International Economics
CNST	The Flinders Centre for Nanoscale Science and Technology
CRC(s)	Cooperative Research Centre(s)
CRDC	Cotton Research and Development Corporation
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
DA	Dairy Australia Limited
DEPI	Department of Environment and Primary Industries
DEXA	Dual X-Ray Absorptiometry
DPI	Department of Primary Industries
DPIPWE	The Tasmanian Government Department of Primary Industries, Parks, Water and Environment
DVC	Data Value Chain
ESCAS	Exporter Supply Chain Assurance System
FP	Food Processing (model)
FRDC	Fisheries Research and Development Corporation
FWPA	Forest and Wood Products Australia
GDP	Gross Domestic Production
GIS	Geographical Information Systems
GNSS	Global Navigation Satellite System

Abbreviations (continued)

Acronym	Meaning
GPS	Global Positioning System
GRDC	Grains Research and Development Corporation
GVP	Gross Value of Production
HD	High Definition
HIA	Horticulture Innovation Australia Limited
ICT	Information and Communications Technology
IoT	Internet of Things
IP	Intellectual Property
LiveCorp	Australian Livestock Export Corporation Limited
MIR	Mid infrared
MLA	Meat and Livestock Australia
NBN	National Broadband Network
NZ	New Zealand
OCM	Objective carcase measurement
OHS	Occupational health and safety
P2D	The Accelerating Precision Agriculture to Decision Agriculture program
QA	Quality Assurance
QDAFF	Queensland Department of Agriculture, Forestry and Fisheries
QUT	Queensland University of Technology
R&D/ RD&E	Research and Development / Research, Development and Extension
RAS/RAT	Robotics and Automation Systems / Robotics and Automation Technologies
RDC(s)	Rural Research and Development Corporation(s)
RIRDC	Rural Industries Research and Development Corporation
RMIT	Royal Melbourne Institute of Technology
SME	Small and Medium Enterprise
SRA	Sugar Research Australia Limited
UNE	University of New England
US	The United States of America
USO	Universal Services Obligation
VRT	Variable Rate Technology
WHS	Workplace Health and Safety

Executive Summary

Digital technologies have the potential to fundamentally transform the way food and fibre is produced, traded and consumed.

A new wave of technologies is enabling farm operators to manage farms with a much higher degree of precision than has been feasible in the past, and when combined with the power of modern computers and big data analytics, is driving the development of sophisticated decision-support tools that allow businesses to make better data-driven decisions.

The overall objective of this research is to develop a business case and clear value proposition for Australian producers, agribusinesses, RDCs, and governments about the potential benefits of decision agriculture.

This is the first project to be supported by all fifteen rural Research and Development Corporations (RDCs), whose levy-paying members reflect the diversity of food and fibre production in Australia. In doing so, it takes a whole-of-agriculture approach to the adoption of digital agriculture technologies and systems, and explores opportunities for improved cross-sectoral industry research collaboration. Recommendations from this report are intended to guide ongoing investments and coordinated action in areas that are likely to address current constraints and accelerate the shift from precision agriculture to decision agriculture.

This report presents results from research covering two broad areas.

Firstly, an analysis of the potential benefit to the Australian economy from the implementation of decision agriculture. This research was conducted with support from the Centre for International Economics (CIE). Findings from this report provide an overview of the potential value to the Australian economy of a 'fully-enabled' decision agriculture. By quantifying the 'size of the prize' and analysing the impact of constraints, this project provides a high-level and strategic overview of the broad opportunities for government and industry to invest in digital agriculture.

Secondly, an analysis of the various aspects that will impact the delivery of those benefits to farmers are reported including likely business models for the delivery of decision agriculture products and services. This includes a review of international developments in decision agriculture and an analysis of their implications for the Australian agricultural industry. Input from AgThentic and US-based consultancy firm Prassack Advisors helped inform this review.

Currently there is a gap in knowledge about the potential economic costs and benefits of digital agriculture, and their impacts on the Australian economy. This report estimates that the unconstrained implementation of decision agriculture would result in a lift in the gross value of agricultural (including forestry and fisheries) production of $20.3 Billion (a 25% increase on 2014–15 levels). In addition, the benefits of unconstrained decision agriculture would have major flow-on effects to other parts of the economy and deliver an overall increase of $24.6 Billion to national gross domestic product (GDP) (a 1.5% increase on 2014–15 levels).

The benefits and drivers of decision agriculture vary by sector, but there are consistent messages about the value of digital agriculture applications such as remote sensing and automation, objective measurement, variable rate management, and improving regulatory compliance. The common challenges and opportunities facing many agricultural sectors reinforce the need for cross-sectoral collaboration in areas that will facilitate the development of decision agriculture.

This project is primarily focused on how technology and data impacts on-farm decision-making. However, many of the biggest changes associated with decision agriculture will occur at other points in the value chain. There are a number of 'push and pull' factors influencing how farmers, processors, retailers and other businesses utilise data and technology to improve decision-making and business profitability. The structure of the value chain, including the size of businesses and the level of business integration between production and retail stages, has a significant effect on the potential for decision agriculture.

The combination of several technological, social and business trends is changing the way businesses in all sectors of the economy operate. We are witnessing the rise of digital entrepreneurs and the proliferation of start-ups, driven in part by changes to the financial sector (e.g. private equity trends). This is leading to digital disruption and the rise of new players who are challenging traditional business models (think Uber in the taxi industry or Airbnb in the hotel industry). The ubiquity of digital technology is leading to the emergence of new business models in agriculture and the development of an AgTech[1] sector.

Currently, the development and uptake of digital agriculture technologies has been underwhelming compared to the associated hype. The Australian market for decision agriculture products and services is in its relative infancy compared to the scale and pace of developments occurring in other parts of the world, notably the United States and Israel. However, the transformation of the Australian agriculture sector into a smart, high-tech industry is showing strong signs of interest and growth. Increasingly, investors and technology developers not traditionally associated with agriculture are recognising the opportunities associated with decision agriculture. As a consequence, the Australian AgTech market is rapidly expanding, with new business models emerging and successful Australian start-ups positioning themselves to benefit from global market opportunities.

The likely emergence of decision agriculture business and service delivery models varies by sector and is shaped by several factors including the market size, potential international technological spillover, and the digital maturity of the sector. Together these factors suggest the potential economic impact of digital agriculture, the specific challenges facing the sector, and readiness of producers to adopt new technology.

[1] The term decision agriculture is used throughout this report to describe a specific set of digital technologies and the purpose of their use. In the investment community, the technologies that are involved in decision agriculture are often described as AgTech.

There are a broad range of data-driven applications and support tools that help guide production decisions using real-time data. This includes supporting decision-making in areas such as nutrient requirements, land use, animal health, climate risks, water efficiency and other production related factors. Products available to farmers extend from general operational and business support systems to more complex and specific, data intensive tools that use algorithms to generate quantitative information (i.e. prescriptive analytics). Decision support tools generate data and provide information for farmers to help solve practical problems and help assess outcomes in a risky farming environment. The challenge for developers is ensuring products are relevant to farmers' needs, simple and easy to use, and perhaps most importantly, deliver a return on investment.

Digital agriculture is a global phenomenon. The international spillover of products, services, and their business models will play a major role in accelerating decision agriculture in Australia. For some products currently available in other markets there are no obvious technology or data limitations to their use in Australia. However, there still may be factors which limit their attractiveness in the Australian market such as market size or lack of partnership opportunity. The successful adoption of other products require integration with specific data sets that may not be readily available in Australia (e.g. soils information), are specific to regulatory compliance for another country, or require a very high level of connectivity infrastructure.

In general, there is expected to be a greater level of activity in globally significant sectors. For example, the grains industry is a major global industry whereas the wool and sheepmeat industries are relatively small by comparison. While this is reflected in terms of where global investment in AgTech is targeted, there are other factors influencing the level of applicability of products to the Australian market.

An important factor in international spillover of technology is the level of similarity in production systems (including genetics, environment, and management practices) between Australia and the country of origin of the product or service. This affects the suitability and transferability of products to meet user needs. For example, Australia's intensive livestock industries (e.g. pork, eggs, chicken meat and dairy) are more similar to those in Europe or North America than is the case for the extensive livestock industries (e.g. beef, sheepmeat, wool). This means it is more likely that 'off the shelf' products or 'plug and play' business models from Europe or North America could be applied in the intensive livestock industries.

Extensive livestock industries and the cropping sector have unique agronomy and environmental challenges and often require integration with datasets specific to the Australian landscape and production context. Corresponding with these differences, the rice, grains, cattle and sheep, and forestry sectors were perceived to have less immediately applicable decision agriculture products and services than other sectors.

Ultimately, it is unlikely that the full economic potential of decision agriculture will be realised until several existing interconnected constraints are addressed, including:

- Issues regarding the availability of appropriate data for analysis e.g. the role of foundational public and cross-sectoral datasets, as well as data governance challenges.

- The availability of decision support tools and analysis capability to make use of the data acquired.
- Issues regarding telecommunications infrastructure and connectivity e.g. addressing both technical and service delivery aspects of connectivity infrastructure.
- Legal and trust issues regarding the systems and protocols governing digital information e.g. clarifying data ownership, control and access issues to facilitate data sharing between multiple participants.
- A lack of a clearly-defined value proposition to potential technology users e.g. the need for commercial validation of a technology's effectiveness (e.g. return on investment).

These constraints affect both the adoption of existing decision agriculture technologies and practices, as well as the likely emergence of new business models (and their associated products and services). In other words, to enable on-farm innovation and innovative business models it is critical that these constraints are addressed.

To support the acceleration of precision agriculture to decision agriculture, there must be initiatives that simultaneously target each barrier. Furthermore, these actions must acknowledge the complex interaction between each of the barriers e.g. to optimise the use of data analytics and decision-support tools there must be, at the same time, improvements to connectivity infrastructure, the underlying foundational datasets, and the resolution of trust and legal issues surrounding data sharing.

The value proposition for decision agriculture will remain substantially as potential rather than delivered until these barriers are addressed. Fortunately, as the potential is understood to be significant (as demonstrated in the economic analysis section of this report), there is considerable pressure to resolve each constraint.

This pressure is being expressed through commercial and market activity (particularly in the field of telecommunications infrastructure) and policy and strategy development from governments and research funders. Resolving each of the barriers described above will result in a marketplace where decision agriculture product developers and service delivery providers will be able to participate to provide solutions which deliver tangible value to agriculture.

Industry (particularly RDCs) and governments have a critical role in facilitating decision agriculture. Given the strategic importance of digital technologies to the future profitability and competitiveness of Australian agriculture, a timely and coordinated response is needed.

This research will help guide ongoing investments by government and RDCs in areas that reduce current barriers to decision agriculture. It will also assist with targeting investments in areas in which there is a strong business case or high-impact productivity and profitability benefits for decision agriculture.

Collaboration between industry stakeholders is essential. New partnerships must be developed between RDCs, advocacy organisations, and industry to address the core cross-sectoral issues at the heart of decision agriculture.

Definitions and Glossary

What is Decision Agriculture?

It is important from the outset to define the differences between decision agriculture, digital agriculture and precision agriculture that have been used by the Accelerating Precision Agriculture to Decision Agriculture (P2D) program. Most people would be familiar with or at least would have heard of digital agriculture however decision agriculture is likely to be a new concept. An understanding of why the term decision agriculture was coined for this project is useful as it informs approaches to this project's methodology and scope, particularly in relation to the economic analysis study reported here.

The P2D program has defined decision agriculture as analysis of digital farm data along with other relevant digital datasets such as soils and environmental data **which leads to** improved, data-driven decision-making by farmers, and enables the use of data-driven technology.

Decision agriculture is enabled by tools and technologies including precision agriculture, the internet of things, digital monitoring systems, cloud computing and many other digital technologies and supporting functions. Decision agriculture is directly enabled by a broad suite of digital technologies and indirectly supported by accumulated knowledge arising from research and development and scientific endeavour.

This definition of decision agriculture was determined in the context of this report as something different from digital agriculture as it recognises that the next step from the use of digital technology (and its associated data) is practice change as a result of analysis of the data acquired. The economic modelling reported here does not focus on the effects of the application of specific technologies but rather the impact of practice and systems change that occur as a consequence of digital agriculture. The 'shocks' that have been applied to the Centre for International Economics (CIE)-Regions Food Processing (FP) model are the estimated accumulated changes that result from multiple digital technologies which together lead to better, data-driven decision-making and adoption of data-driven technology i.e. decision agriculture.

Table 2.1 lists some key terms that are sometimes used interchangeably in the discussion of decision/digital agriculture with the definitions that have been adopted for the purpose of this report.

Table 2.1 Glossary of key terms

Term	Meaning
AgTech	Commonly used in the investment community to describe digital technologies used in agriculture.
Big Data	Computerised analytics systems that interrogate extremely large databases of information in order to identify particular trends and correlations.
Cloud computing services	Cloud storage is a model of data storage where the digital data is stored in logical pools, the physical storage spans multiple servers (and often locations), and the physical environment is typically owned and managed by a hosting company.
Decision agriculture	Conclusion or action resulting from the application of knowledge and/or information that may be derived from digital agriculture.
Digital agriculture	Digital agriculture typically involves both the collection and analysis of data to improve both on- and off-farm decision making leading to better business outcomes.
Digital disruption	Digital and associated technologies that 'disrupt the status quo, alter the way people live and work, rearrange value pools, and lead to entirely new products and services', often in a relatively short period of time (Manyika et al., 2013).
Information and communication technologies (ICT)	ICT is a broad term used to refer to technologies that involve the use of computers, computer networks, telephone networks and internet networks to manage data and information.
Internet of Things	Devices such as sensors, machines, and other digital instruments which are connected to each other and the internet so that they are able to collect and exchange data with each other.
Open Data	Data that is: 1. freely available to download in a reusable form. Large or complex data may be accessible via a service or facility that enables access in-situ or the compilation of sub-sets 2. licensed with minimal restrictions to reuse 3. well described with provenance and reuse information provided 4. available in convenient, modifiable and open formats 5. managed by the provider on an ongoing basis.
Precision agriculture	Farming practices that involve precise spatial management through the use of GPS (Global Positioning System) technologies. This can include variable rate seeding and fertiliser application, yield mapping, and animal location and analysis.

Introduction

The Research Question / Context

The Accelerating Precision Agriculture to Decision Agriculture Rural R&D for profit program (P2D) is investigating a range of enabling functions that will support decision agriculture (*Figure 2.1*). These include:

- the availability of appropriate data;
- the availability of decision support systems that can utilise that data,
- data connectivity;
- a clear understanding of the value propositions arising from adoption; and
- trust in systems and protocols used to manage digital information.

These functions have all been identified as essential for the benefits of decision agriculture to be realised.

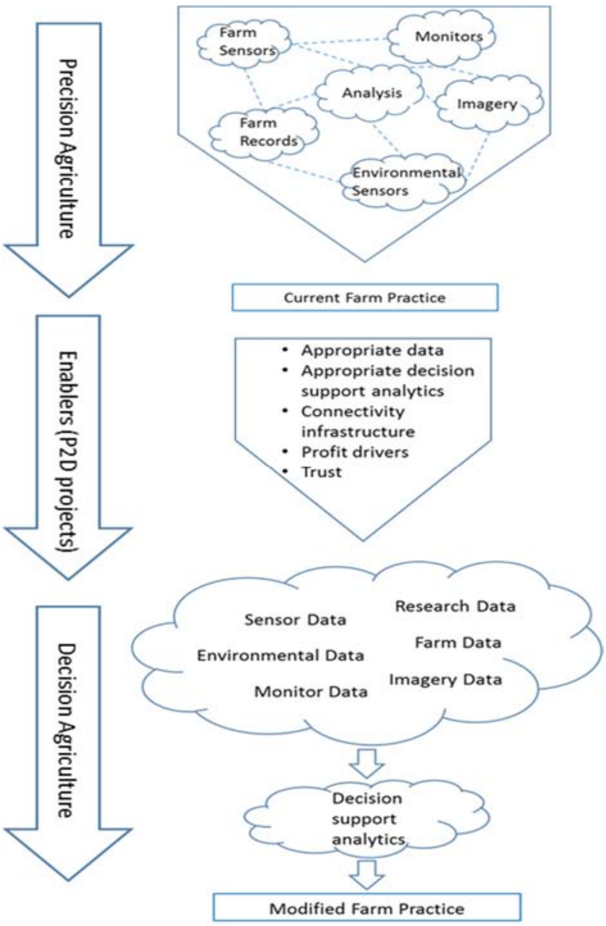


Figure 2.1 P2D Program Framework

Business models that are utilised to deliver the associated products and services of decision agriculture, whether they are delivered by small start-ups, large companies, research agencies or governments, will all in some way be constrained by the enabling functions listed above and how those vary within agriculture sectors and geographies.

For research funders, including Rural Research and Development Corporations (RDCs), to be able to develop informed options that ensure investment activities facilitate the development of decision agriculture for relevant stakeholders, it is important that they have a clear understanding of the potential business models and platforms for delivery of decision agriculture products and services.

Project Scope

This project explores the role and potential impact of digital technologies in improving decision-making for businesses in Australia's agricultural, forestry and fisheries industries. It is the first project to be supported by all fifteen RDCs, whose levy-paying members reflect the diversity of food and fibre production in Australia. It seeks to provide an overview of the potential value to the Australian economy of a 'fully-enabled' decision agriculture. In doing so, it discusses the (opportunity) costs associated with major constraints to digital agriculture, including: the availability of appropriate data, and the availability of decision support systems that can utilise that data; data connectivity; a clear understanding of the value propositions arising from adoption; and, trust in systems and protocols used to manage digital information.

By quantifying the 'size of the prize' and analysing the impact of constraints, this project provides a high-level and strategic overview of the broad opportunities for government and industry to invest in digital agriculture. This project will help inform ongoing research and investment in areas that will support the acceleration of precision agriculture to decision agriculture.

This project is primarily focused on how technology and data impact on-farm decision-making. However, it also recognises that many of the biggest changes associated with decision agriculture will occur at other points in the supply chain. There are a number of 'push and pull' factors influencing how farmers, processors, retailers and other businesses utilise data and technology to improve decision-making and business profitability. The structure of the supply chain, including the size of businesses and the level of business integration between production and retail stages, has a significant effect on the potential for decision agriculture.

One of the key drivers for this project is the need to identify a strong business case and value proposition for decision agriculture. This project investigates the likely business and service delivery models that will develop decision agriculture products and services. Currently, the development and uptake of decision agriculture has been underwhelming compared to the associated hype. The report considers international experiences in decision agriculture, with a particular focus on the US and Europe. Decision agriculture and related Big Data applications are more advanced in the cropping sector of the US than is the case in Australia, and are generally more developed in the cropping than livestock sectors. In some Australian sectors, there is potential for the international 'spillover' of technologies from other regions.

Project Outputs

The overall objective of this research is to develop a business case and clear value proposition for Australian producers, agribusinesses, RDCs, and governments about the potential benefits of decision agriculture. The key outputs from this project are an estimate of the potential benefit of decision agriculture to the Australian economy, as well as information about the likely business models that will deliver the products and services through which these benefits will be realised.

Report Structure

The remainder of this section provides a **Background** on key concepts discussed in the report and outlines the project's **Methodology**, including how the economic modelling and business model analysis was conducted.

The remainder of this report is structured as follows:

Section 3 **The potential economic impact of decision agriculture** presents key findings of the economic modelling, including the potential impact of unconstrained decision agriculture on the Gross Value of Production (GVP) of individual sectors and the wider impact on the Gross Domestic Product (GDP) of the Australian economy.

Section 4 **Business and Service Delivery models for decision agriculture** reviews recent literature on business models, value propositions and Lean and Agile approaches to business development. This section also summarises key findings about factors affecting the emergence of new business models for decision agriculture in Australia, including market size, international spillover, and the digital maturity of a sector.

Section 5 **The impact of current constraints on decision agriculture** discusses how a range of constraints are influencing the current utilisation and future development of digital agriculture.

Section 6 provides a **Conclusion** summarising key findings from the report. It also outlines **Recommendations** that industry (including RDCs) and government stakeholders can implement to accelerate the development of decision agriculture.

In addition, there are five *Appendices*:

Appendix 1 provides further information on the **CIE Food Processing Model** – a general equilibrium model used to forecast the economic benefits of decision agriculture to individual sectors and their flow-on effect to the wider Australian economy.

Appendix 2 contains the results of the **Economic Impacts of Decision Agriculture by sector**. This includes an overview of the sector, the key drivers of decision agriculture, the potential economic impacts of decision agriculture, and the implications for business and service delivery models.

Appendix 3 provides an extensive review of products and services currently available in the **Australian AgTech market.**

Appendix 4 discusses the **Global Impact of Digital Agriculture with a focus on** key international developments, and their implications and potential spillover to Australian agriculture. This work was undertaken by US-based consultancy firm Prassack Advisors LLC.

Appendix 5 provides three detailed digital agriculture **Case studies from the US** (Agrian, Farmers' Business Network, and HarvestMark). This work was undertaken by Australian agricultural technology consultancy firm AgThentic.

Background

The development of digital technology for agriculture capable of generating objective information about the status of soil, water, crops, pasture and animals is quickly changing the ways in which farm businesses can be managed. Digital technology has the potential to enable producers to manage enterprises with a much higher degree of precision than has been feasible in the past. When combined with the power of modern computers and Big Data analytics, it has enabled the development of sophisticated decision-support tools that can assist farm managers to make better data-driven decisions.

This project examines the mechanisms by which precision agriculture is being accelerated to decision agriculture, by defining the economic case for its adoption, and listing the barriers preventing the complete realisation of the prospective benefits. It also explores the potential value proposition(s) being offered to farmers in support of decision agriculture products and services.

Industry consultations conducted as part of this project highlighted the wide acknowledgment of the potential for decision agriculture to fundamentally change food and fibre production and their associated value chains. However, identifying where, when, and by how much decision agriculture will impact production and the subsequent implications is less clear. Rapid advances in digital technology and data applications are emerging to support production management decisions, maintain and report on biosecurity issues, support quality assurance and credence systems, map and analyse land use and crop performance, monitor and manage water, track markets and sales transactions and purchases.

Agriculture has experienced several major revolutions over the past century (*Table 2.2*). The first was the mechanical revolution that occurred in the years between the first and second world wars, during which time, horse power was replaced by mechanical power, leading to dramatic improvements in productivity. The second was the scientific revolution (often referred to as the green revolution), which occurred over the period of the late 1960s to the late 1990s, and involved the application of well-developed science including chemistry, again resulting in significant productivity increases. The third wave of agricultural innovation, arguably, was the development of precision farming technologies and techniques, of which, the initial uses involved GPS positioning of machinery to introduce operating efficiencies and precise control. Subsequent developments in precision agriculture have involved the use of proximal and remote imagery, precise application of inputs and remote animal monitoring and measurement. Some have suggested that we are now entering a fourth wave of agricultural innovation, where, as the cost of digital technology reduces and computing power increases, the capability to collect, aggregate and analyse huge amounts of data from digital and precision agriculture is creating entirely new opportunities for providing insight into agricultural business and production, and assisting with decision-making.

Table 2.2 The four revolutionary waves of agricultural innovation. (Source: Zuckerberg & Kennes, 2017)

Wave	Description
First Wave	Mechanisation (seed drill, cotton gin, reaper/binder, combined harvester-thresher, tractor)
Second Wave	Agricultural chemistry (nitrogen fertiliser, pesticides)
Third Wave	Precision farming (biology, plant and animal genetics, GPS)
Fourth Wave	Digital agriculture (smart hardware, analysis of temporal layers of spatial data, weather, and remote sensing to evaluate crop conditions)

The flood of digital information that can now be generated as a part of normal farm operations is leading to questions about how the information should, or can, be stored, managed and utilised in ways that enhance productivity and profitability. The early indications are that the digital revolution will create very important opportunities for productivity gains, but will require a combination of scientific knowledge, computing applications and human resource development for those gains to be realised through decision agriculture (the practice change resulting from digital agriculture).

The ability of digital agriculture to assist in more intensive and data-driven farm management decisions enables farmers to economically change from paddock and herd average management, to square metre and individual animal management, with consequent increases in farm productivity. This project provides a robust analysis of the likely economic impact of technology on-farm productivity, and the flow-on value effect on supply chains and the wider economy.

Project Objectives

The primary objective of this research is to describe a clear value proposition for Australian producers, RDCs, and other supply chain actors in relation to the delivery of the potential benefits of decision agriculture.

This research includes a structural analysis of each agricultural sector (including fisheries and forestry), and examines the enabling factors most likely to facilitate a move from precision agriculture to decision agriculture. This research will estimate the potential economic gains for the agricultural sector and associated supply chains arising from the adoption of decision agriculture. It will also explore the business models and strategies that are likely to support the continued development of products and services supporting decision agriculture in Australia.

Drivers of Decision Agriculture

There are a number of 'push' and 'pull' factors which are driving developments in digital agriculture (*Table 2.3*). Many of the push factors relate to technological advances, which are reducing existing barriers (e.g. connectivity, data storage, and data analytics) and creating opportunities for innovation. At the same time, there are several pull factors which are encouraging users to adopt new digital technologies. These include business/ market drivers, such as opportunities to improve business decision-making, and public drivers, such as the role of food safety and traceability regulation.

Table 2.3 A summary of Push and Pull factors driving Decision Agriculture. (Sources: Wolfert, Ge, Verdouw, & Bogaardt, 2017; Beecham Research, 2014)

Push factors	Pull factors
• **General technological developments** o Internet of Things (IoT) and data-driven technologies o Precision Agriculture o Rise of AgTech companies • **Sophisticated technologies** o Global Navigation Satellite Systems o Satellite imaging o Advanced (remote) sensing o Robotics o Unmanned Aerial Vehicles (UAVs) • **Data generation and storage** o Improved data management technologies e.g. cloud-based storage o Process-, machine- and human-generated o Interpretation of unstructured data o Advanced data analytics • **Digital connectivity** o Roll-out of National Broadband Network (NBN) o Development of new connectivity technologies and private networks o Computational power increases • **Innovation possibilities** o Open farm management systems with specific apps o Remote/ computer-aided advice and decisions o Regionally pooled data for scientific research and advice o New business and supply chain models	• **Business drivers** o Efficiency increase by lower cost price or better market price o Improved management control and decision-making o Better local-specific management support o Better cope with legislation and paper work o Deal with volatility in weather conditions o Growing demand (and price premiums) for products with certain quality traits e.g. provenance information o Declining cost of sensors and computational technologies • **Public drivers** o Food and nutrition security o Food safety and Traceability o Sustainability • **General need for more and better information** o Shift from experiential decision-making to data-driven decision-making ('you can't manage what you can't measure')

The Age of Data and Analytics

The shift from precision to decision agriculture is fundamentally about the new ways in which data is being collected and analysed to give users greater management insight. *Figure 2.2* illustrates some of ways that data is collected across the agricultural landscape.

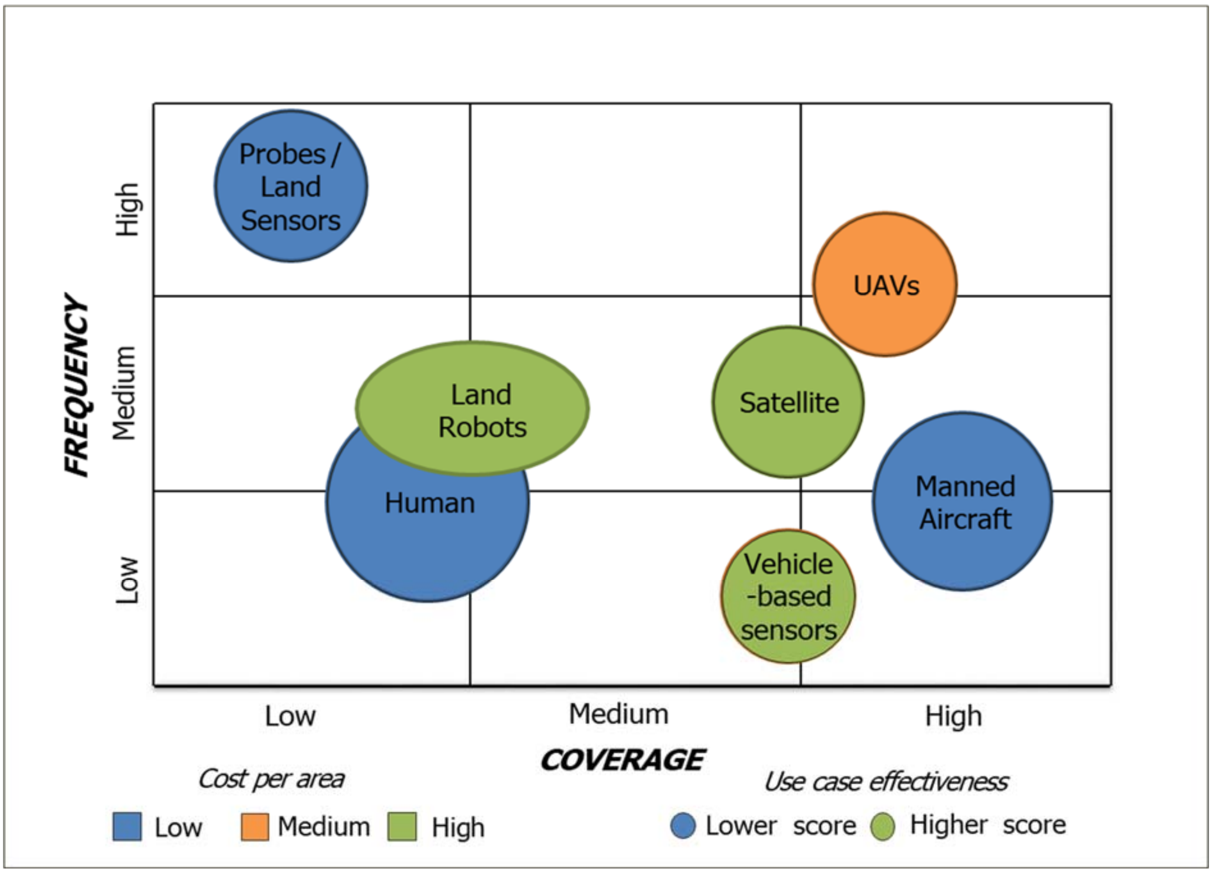


Figure 2.2 Data collection dimensions; frequency, coverage, use case effectiveness and cost. (Source: Prassack Advisors, 2017)

The data collected from these processes are used to describe two categories of outcomes – performance and cost:

- Improve performance: e.g. increase crop yield, improvements in quality, higher utilisation of equipment, etc.
- Manage costs: e.g. reduce (or optimise) key input costs (fertiliser, pesticides, seed, water etc.)

Secondary focus areas include environmental impact (e.g. nitrogen run-off, water conservation), risk management, and information for provenance, compliance and traceability purposes. Much of the data (irrespective of the platform) will be collected via sensors. *Figure 2.3* describes some sensor categories and their applications.

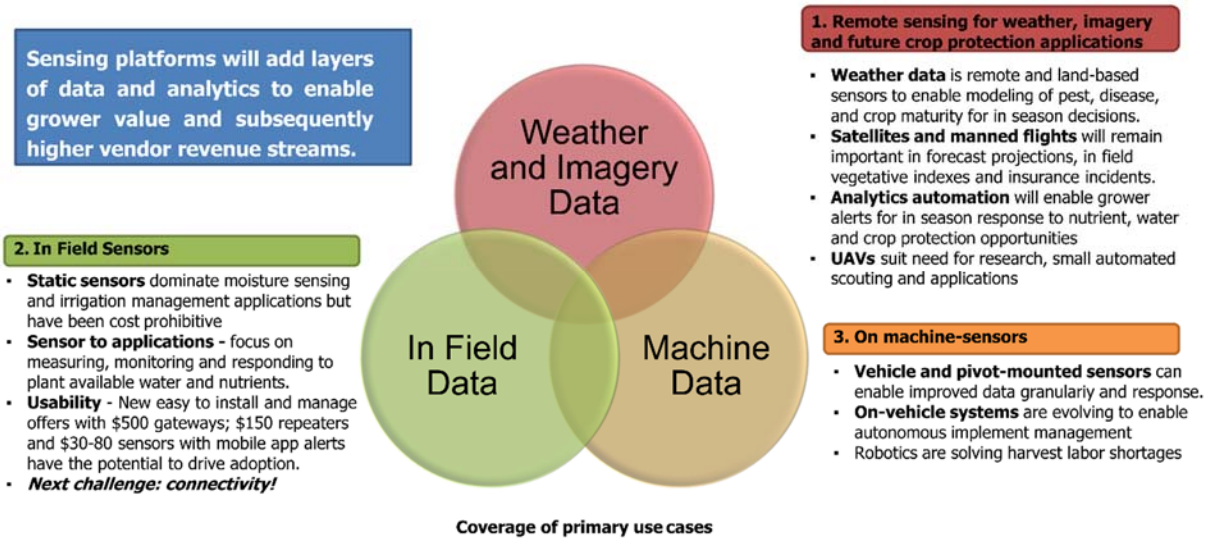


Figure 2.3 Sensor categories. (Source: Prassack Advisors, 2017)

Once data has been collected the critical step of analytics is required to convert the data into actionable information and ultimately knowledge. Analytics is slowly shifting its focus towards real-time, predictive, and prescriptive analytics. Technologies and business models are emerging that give users deeper and more timely information that can drive proactive decision-making.

Currently, the focus of most digital agriculture products and services is on the area of **Descriptive** or **Diagnostic Analytics**. This is generally focused on answering questions such as what happened in the past and why. Users gain insight from historical data using reporting, benchmarking etc. For example, this could involve understanding the correlation between fertiliser application rates and crop yields.

There is growing interest in **Real-Time Analytics**, which describes what is currently happening. For example, this could include the visualisation of the current status of equipment. Developments in sensors and remote monitoring technologies are driving major opportunities for businesses using real-time analytics.

The area of **Predictive Analytics** has the potential to drive major productivity improvements on farms and across supply chains. Predictive analytics focuses on understanding what could happen. This could entail algorithms that engage in the forecasting of future incidents (e.g. predicted yield). The main goal of predictive analytics is to identify potential issues before they occur. Most often predictive analytics use statistical and machine learning techniques.

The most complex, but potentially valuable area of analytics, is **Prescriptive Analytics**. Prescriptive analytics answers the 'what should happen' type of question and provides advice on the best possible actions that the end-user should take. Prescriptive analytics requires a predictive model with two additional components: actionable data and a feedback system that tracks the outcome produced by the action taken. For example, an algorithm which suggests the optimal recipe of inputs to produce the most profitable crop. *Figure 2.4* summarises the key features of the four types of analytics.

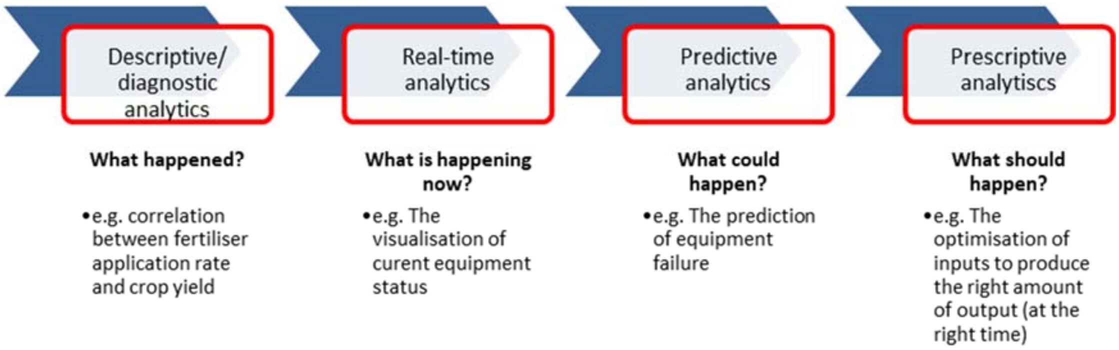


Figure 2.4 The shift towards real-time, predictive, and prescriptive analytics. (Source: IoT Analytics, 2016)

An example of extent of data collection and analysis possible as applied in a cropping scenario is demonstrated in *Figure 2.5*.

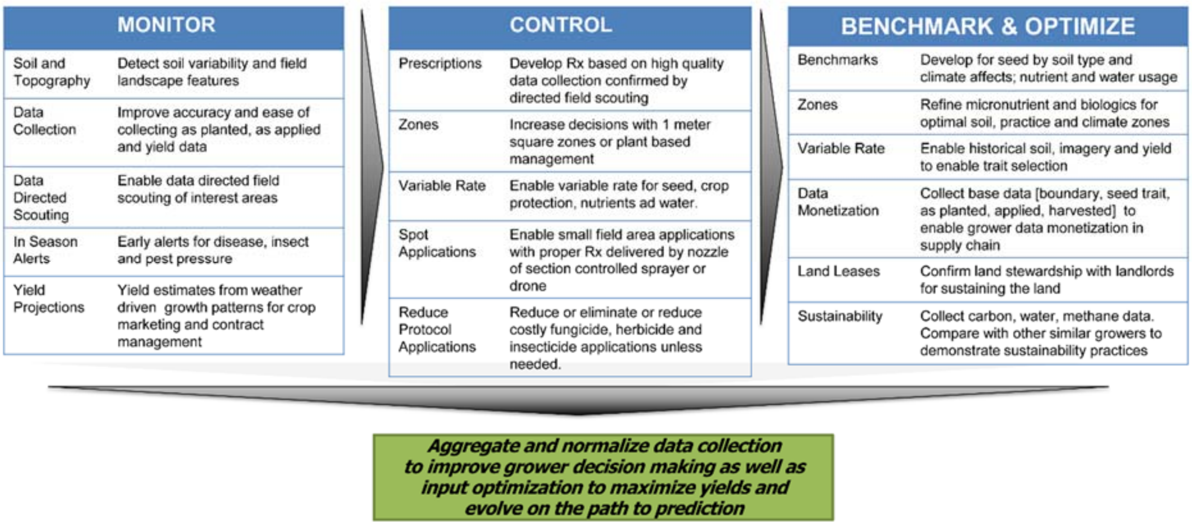


Figure 2.5 Data management innovation in the cropping sector. (Source: Prassack Advisors, 2017)

One of the major disruptors in decision agriculture is the potential for data exchange to go well beyond the farmgate and flow through the value chain to provide information to processors and consumers about farm produce. Equally, data from consumers and processors will be available to farmers to enable decisions based on post-farmgate profitability factors such as quality and provenance. This data flow can be described as the digital value chain.

The Digital Value Chain

The collection and utilisation of data in Australia's agricultural, forestry and fisheries industries is not new, however innovation and the decreasing cost of technology is increasing the volume, veracity and variety of data collected. As the quality and quantity of real-time data that can be obtained at the pre, and post-farmgate level increases, its value and importance in decision-making processes is also increasing, becoming an increasingly important factor contributing to the value of agriculture, forestry and fisheries products and processes. Subsequently, the traditional agribusiness value chain is evolving to one which places as much importance on data about the product as on the product itself.

There are many types of production data generated on-farm or on-site, including but not limited to, agronomic, animal, financial, compliance, meteorological, environmental, machine and staff data. The data is generated from a variety of increasingly powerful, and cost-effective sources such as machinery, drones, Global Navigation Satellite Systems (GNSS), remote sensors, satellites, and smartphones. For value chain purposes, production data is supplemented by data from other sources such as service providers, advisory bodies, public authorities, and increasingly from processors, retailers and other stakeholders dispersed along the value chain.

The concept of a value chain was popularised by Porter (1985) to describe or model the chain of value-adding activities that support the delivery of a product or service to the market. Value chains encompass both supply chain and demand (i.e. consumer) chain concepts with a focus on the role of information and relationships at all stages from input supply to final consumption. While the terms supply chain and value chain are frequently used, the two terms are not interchangeable, with the common distinction being that supply chains are production-driven, whereas value chains are consumer-driven.

A value chain is made up of a series of sub-systems each with inputs, transformation processes, and outputs. The same series of sub-systems exists for data in digital value chains (*Figure 2.6*).

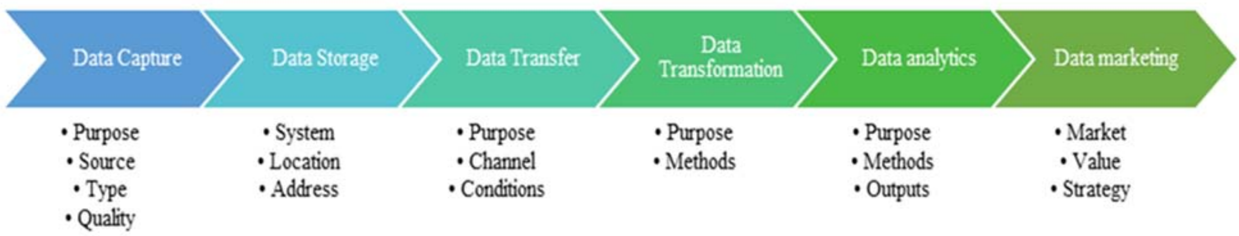


Figure 2.6 Data in the value chain. (Sources: Wolfert et al., 2017; Chen, Mao & Liu, 2014)

The relationship between different firms (e.g. producers, farmers, and processors) is directly affected by the structure of the value chain. Factors such as the size and market power of different firms, complexity of transactions, and information/ data flow influence the governance of this relationship (Gereffi, Humphrey & Sturgeon, 2015).

There are many barriers that limit collaboration in a value chain. Some of these factors relate to the structure and governance of the industry. This includes the size of firms, power asymmetries between different firms, and the length of the supply chain (e.g. number and complexity of processes involved in different stages between producer and consumer). Other factors relate to characteristics of individual firms including their motivation, risk preferences, and management capabilities. Poor relationships reflect a lack of trust, conflicts of interest, and limited sharing of benefits.

Information flow is one of the most important factors affecting collaboration between different firms. Curry (2016), notes information flow in the Data Value Chain (DVC) as a series of steps needed to generate value and useful insights from data. A well-functioning, working data ecosystem is defined as one that bring together the key stakeholders with a clear benefit for all. Curry (2016) identified the key actors as:

- **Data Suppliers:** Individual/organisation (Large and Small-to-Medium Enterprises (SMEs) that create, collect, aggregate, and transform data from both public and private sources.
- **Technology Providers:** Typically, organisations (Large and SMEs) who provide tools, platforms, services, and know-how for data management.
- **Data End Users:** Individual/organisation from different industrial sectors (private and public) that leverage Big Data technology and services to their advantage.
- **Data Marketplace:** Individual/organisation that host data from publishers and offer it to consumers/end users.
- **Start-ups and Entrepreneurs:** Develop innovative data-driven technology, products, and services.
- **Researchers and Academics:** Investigate new algorithms, technologies, methodologies, business models, and societal aspects needed to advance Big Data.
- **Regulators** for data privacy and legal issues.
- **Standardisation Bodies:** Define technology standards to promote the global adoption of Big Data technology.
- **Investors, Venture Capitalists, and Incubators:** Individual/organisation that provides resources and services to develop the commercial potential of the ecosystem.

The digital value chain constitutes optimisation based decision-making, a process by which the integration of data from all areas of the production and supply chain are brought together, thus leveraging data across the entire value chain. Unconstrained, these processes have the potential to increase accuracy and efficiency in supply chain management for businesses across all sectors of the economy.

Methodology

The research reported on here covers two broad areas: firstly, an analysis of the potential benefit to the Australian economy from the unconstrained implementation of decision agriculture is presented; and secondly, various aspects that will impact the delivery of those benefits to farmers are reported including likely business models for the delivery of decision agriculture products and services.

Benefits to the economy were predicted using the Centre for International Economics (CIE)-Regions Food Processing model (CIE-Regions FP model), a general equilibrium model of the Australian economy with a focus on agriculture and food processing (see *Appendix 1* for additional information).

Step 1. Potential from unconstrained decision agriculture.

The potential of unconstrained decision agriculture was determined by estimating the cumulative impact of several factors, the first being the increase in productive potential delivered by digital technologies.

There are three critical factors which determine the productive potential of a plant or animal:

- The genetic potential of the plant or animal;
- The environmental limitations placed on realising the genetic potential; and
- The decision-making or management that exploits genetic potential within environmental limitations.

While farmers have very little control over the first two points, the third point is the application of production management skills and decision-making, which is completely in the control of the producer. A full implementation of decision agriculture would deliver producers, in a timely fashion, all the data, information and analysis that they need such that all the constraints on productivity that are within the control of the producer are eliminated. In this case, the productive potential would only be limited by the genetic potential and environmental limitations for which the producer has no control.

The economic benefit from productivity improvements that can be assumed to result from fully adopted decision agriculture therefore becomes the difference between the genetically and environmentally limited yield, and current production practice - in which productivity may be constrained by management decisions as well as genetic and environmental potential.

The ability to determine unconstrained productive potential will differ between agricultural sectors. The grains sector for example is relatively advanced in this area with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) led *Yield Gap* project (www.yieldgapaustralia.com.au). While other sectors may not be as advanced in being able to quantitatively define the Yield Gap, the rationale supporting the concept can be widely understood, and informed opinion given on potential improvement.

The productive potential information used for this project was obtained through a series of interviews with experts identified by each participating RDC. The interviews followed a structured process of defining best practice and then applying known improvements that result from implementation of decision agriculture. The interviews also posed a series of “what if?” scenarios relating to access to data, appropriate analytics, unconstrained connectivity, and level of adoption of digital technology.

The shocks that were applied to the CIE-Regions FP model were determined by grouping suites of similar technologies into production factors or key decision areas. For example, for the grains sector, better nutrient application was identified as a single shock since the contribution that better nutrient application has to the overall yield gap could be estimated and better nutrient application encompasses a suite of digital applications. Likewise, for the beef industry, animal health and monitoring has been identified as a shock since the contribution that increased animal health makes to productivity improvement can be reasonably estimated, and there is a distinct grouping of digital technologies that provide information for this factor.

The methodology used to forecast the unconstrained potential of decision agriculture for each sector can be considered a ‘top down’ approach, however, it has been tempered wherever possible with rigorous ‘bottom up’ ground-truthing through comparison to benchmarking information or other known and measurable productivity figures. If there was not clear information available about unrealised genetic potential then benchmarking studies were examined, so that estimations of possible improvement did not go beyond what is known to be possible and being achieved by the very top producers. Due to this approach being taken, the authors believe that the modelling results are relatively conservative as they do not forecast improvements beyond what is known to be achievable.

It is important to remember however, that the shocks applied to the CIE model estimate the size of the opportunity under a best-case scenario. How much of that opportunity is realised is highly dependent on an array of factors and may differ significantly between sectors. The GVP increases estimated for each sector are intended to be a guide for the potential of digital agriculture and the authors acknowledge that industry structural differences, economic and trade circumstances will determine the ultimate growth of each industry.

Through the consultative phase of the project there were also several impacts of decision agriculture that were suggested to the research team as significant but were not included in the CIE-Regions FP modelling. These were impacts related to issues such as biosecurity and traceability. The ability for decision agriculture to provide platforms to better monitor biosecurity impacts was almost universally acknowledged, however attributing a financial benefit to better monitoring was problematic since biosecurity platforms do not provide immediate improvement but instead provide insurance against market loss. Since the purpose of this study was to forecast the immediate benefit to the economy of unimpeded decision agriculture the research team decided that biosecurity, traceability and similar issues lay outside the scope of the analysis. These issues have been included in the commentary as there is no doubt that decision agriculture will deliver significant benefits, however they have not been included in the economic modelling.

Step 2. Impact of enabling functions on realising productive potential of decision agriculture.

The full adoption of decision agriculture resulting in the realisation of unconstrained potential is unlikely for several reasons, some of which are the limited application of the enabling functions of decision agriculture as investigated by the P2D program.

An estimation of the extent to which each of those enabling functions individually acts as a barrier to the unconstrained potential of decision agriculture is confounded by the way that they are inextricably linked to each other. The enabling functions that the P2D program has investigated include:

- Appropriate data;
- Appropriate decision support analytics;
- Connectivity infrastructure;
- Value propositions; and
- Trust.

While each of these enablers is important in their own right, each also depends on the others in the context of the full expression of decision agriculture. For example, trust issues can be overcome more easily by compelling value propositions, which in turn create a market pull for the installation of connectivity infrastructure, and facilitate the aggregation of useful data.

The linked nature of these enabling functions requires that they be thought of as a set of infrastructure and policy requirements that need to be implemented simultaneously to enable decision agriculture. If any one of these enabling functions remained as a barrier, it would limit the full expression of decision agriculture.

To this end, the methodology used in determining the impact of enabling functions on the economic benefit that may be realised has been qualitative rather than quantitative. Commentary has been provided on how each of the enabling functions may impact on the shocks applied to the CIE-Regions FP model however in terms of a financial impact they have all been considered to have equal effect.

The business models component of this project included an extensive literature review to provide insight on the prevalence of various types of business models in the technology and start-up community. This information was overlayed with observations obtained from the industry and agribusiness workshops conducted throughout the length of the P2D program as well as information provided from Prassack Advisors regarding international trends and opportunities.

The impact of enabling functions of decision agriculture was considered in relation to the likely development of these business models across the various sectors in Australian

The Potential Economic Impact of Decision Agriculture

Background

Decision agriculture will have a substantial impact on Australia's agriculture, forestry and fisheries industries. The economic modelling described in this section has attempted to estimate the impact of decision agriculture at a sectoral level, and importantly the impact to the entire economy.

The technologies and enabling functions that support decision agriculture are not sector specific. Connectivity infrastructure, many of the required datasets, data ownership policy etc. are required for decision agriculture universally. It is important therefore to quantify the benefit to the whole of the economy of a fully enabled decision agriculture so that funding and policy responses to issues associated with implementation can be assessed on a whole of economy basis.

This is one of key premises of the Australian Government's 'Rural R&D for Profit' program, through which this project is funded. This program recognises the need for collaborative research to address cross sectoral issues with implications for all of agriculture. Many of the enabling functions and technology requirements for decision agriculture are common to all sectors. As such, it is important that research, development and extension for decision agriculture is collaborative and cross-sectoral to meet the needs of all farmers.

This project addresses the gap in the current knowledge by providing a robust economic analysis of the potential impact of decision agriculture on the Australian economy. The productivity and profitability gap between the current situation and a fully-enabled decision agriculture reflects the size of the opportunity. The shocks that have been applied to the model estimate the absolute unconstrained potential if the opportunities presented by decision agriculture are adopted 100%. That opportunity currently remains uncaptured due to barriers which the P2D program has investigated including; connectivity infrastructure, trust barriers, a lack of appropriate datasets and decision support tools, and poorly defined value propositions.

The model that was used in this analysis is the Centre for International Economics (CIE)-Regions Food Processing Model (CIE-Regions FP model) (*Appendix 1*). The process used to determine the inputs to the model is described in the Methodology section of the Introduction (Chapter 2). The modelling involved the establishment of a baseline value of output for the agriculture sector, and subsequent modelling of the impact of decision agriculture based on assumptions about the impact of various new technologies or 'shocks'. Broadly, the shocks applied to the model were determined through a combination of academic and industry literature, consultation with Rural Research and Development Corporation (RDC) representatives and industry experts, benchmarking studies, and industry workshops conducted as part of the P2D project.

A **summary** of the results of the analysis and broad commentary is contained in the following section. A **more detailed analysis** including sector summaries and descriptions of each productivity shock and the gross value of production (GVP) and gross domestic production (GDP) impact of each shock is contained in *Appendix 2*. The descriptions of the shocks contained in the tables in *Appendix 2* provide information about whether it is a 'yield gap' related productivity shock or some other factor (e.g. processing in vertically integrated industries).

Key Findings

The Impact of Unconstrained Decision Agriculture to the Australian Economy

Table 3.1 summarises the potential benefit of unconstrained decision agriculture to each sector (GVP) and the Australian economy (GDP). The modelling results are based on assumed productivity gains for each sector, and are further detailed in *Appendix 2*.

Table 3.1 The impact of unconstrained decision agriculture to the Australian economy.

		Potential benefit to the sector		Potential benefit to the economy
Sector	Baseline sector value (GVP) 2014-2015 ($m)	GVP[1] Increase ($m)	GVP Increase (%)	GDP[2] Increase ($m)
Rice	260	78	30	46
Grains[3]	11,522	5,930	51	1,821
Cotton	1,413	394	28	692
Sugar	1,257	291	23	660
Horticulture[4]	1,018	403	40	951
Beef	10,461	1688	16	4,219
Sheepmeat	2,988	516	17	1,316
Wool	2,550	452	18	1,128
Pork	1,084	55	5	429
Dairy	3,343	497	15	1,298
Eggs	729	180	25	128
Chicken Meat	2,084	503	24	371
Wine	5,865	706	12	630
Forest and Wood Products	14,864	5,511	37	7,484

(Table continued over page)

[1] *Gross Value of Production (GVP)* measures the actual production output of an establishment or sector.
[2] *Gross Domestic Product (GDP)* is a summary indicator of economic activity, and measures the sum of the gross value added through the production of goods and services in individual sectors of the economy
[3] Including oilseeds and pulses.
[4] Leafy greens, brassicas, and carrots only.

Sector	Baseline sector value (GVP) 2014-2015 ($m)	Potential benefit to the sector GVP[5] Increase ($m)	Potential benefit to the sector GVP Increase (%)	Potential benefit to the economy GDP[6] Increase ($m)
Livestock Exports	1,601	72	4	179
Red Meat Processing	14,533	2081	14	2,438
Fisheries and Aquaculture	2,132	928	44	855
Total	**75,331**	**20,285**	**25**	**24,645**

The modelling estimated that the unconstrained implementation of decision agriculture would result in a lift in the value of agriculture of $19.1 Billion (25%) and an increase of $24.3 Billion to national GDP (1.5%). All farm and post-farm sectors were estimated to benefit from decision agriculture with the cropping sectors potential proportional increase in GVP generally larger than the animal industries, however the benefit to the economy (increase in GDP) was estimated to be larger from the animal industries.

The baseline GVP figures used in this model are the 2014-15 official statistics for the sector. Increased commodity prices and production across most of agriculture in 2016-17 have resulted in a significant increase to the farmgate value of agriculture from $54.4 Billion[7] to $63.8 Billion (ABARES, 2017). The total benefit derived from decision agriculture would therefore be anticipated to be larger if this increase was to be maintained, however the proportional increase should be similar.

Key Finding

If decision agriculture was fully implemented it would deliver an estimated boost to the value of agriculture of 25% ($20.3 Billion) and lift the Australian economy by an estimated 1.5% ($24.6 Billion).

Sectoral Breakdown

The relationship between producers and processors and the way that decision agriculture will depend on data flowing through digital value chains is commented on in many other sections of this report. For the purposes of the economic modelling presented here for the pre-farmgate industries, as far as possible the shocks applied and impact measured has been

[5] *Gross Value of Production (GVP)* measures the actual production output of an establishment or sector.
[6] *Gross Domestic Product (GDP)* is a summary indicator of economic activity, and measures the sum of the gross value added through the production of goods and services in individual sectors of the economy
[7] The baseline sector value in Table 3.1 of $60.8 Billion is higher than the ABARES figures for 2014-15 of $54.5 Billion as it includes some post farmgate processing activity.

limited to activities for which decisions are made at a farm level. The data which is contributing to those decisions may come from beyond the farmgate, however the decision made is an on-farm decision.

Some sectors however are structured such that it is much more difficult to separate pre-, and post-, farmgate benefits from decision agriculture. These sectors have been grouped in the vertically integrated sectors section.

Cropping Sector

Table 3.2 displays the productivity shocks that were modelled for the cropping sectors and the corresponding impact on GVP.

Table 3.2 Productivity shocks and corresponding increase in GVP for cropping sectors

Sector	Practice	Productivity improvement modelled (%)	Increase in GVP (%)
Rice	Fallow Weed Control	1.03	2.90
	Irrigation scheduling and application	5.32	15.00
	Crop Nutrition	1.62	4.57
	In-crop weed and pest control	0.28	0.79
	Labour saving	2.44	6.86
		10.69	**30.12**
Grains	Fallow Preparation	0.98	2.98
	Crop rotation	5.00	15.24
	Planting	3.28	10.00
	Crop nutrition	2.85	8.68
	Crop protection and Weed control	0.26	0.79
	Labour saving	2.50	7.62
	Yield forecasting	2.00	6.10
		16.86	**51.41**
Cotton	Crop Nutrition	11.66	7.03
	Crop Protection and Weed Control	1.57	0.95
	Operational efficiencies	0.85	0.51
	Irrigation scheduling and application	17.00	10.25
	Labour Savings	3.88	2.34
	Optimising quality	10.29	6.21
	Marketing	0.24	0.15
	Reduction in supply chain cost	0.81	0.49
		46.30	**27.92**
Sugar	Fallow preparation	0.69	0.30
	Crop rotation	10.00	4.38
	Planting	13.45	5.89
	Crop nutrition	17.72	7.76
	Crop protection and weed control	1.74	0.76
	Labour saving	4.20	1.84
	Harvest and processing scheduling	5.00	2.19
		52.79	**23.12**

(Table continued over page)

Sector	Practice	Productivity improvement modelled (%)	Increase in GVP (%)
Horticulture	Paddock preparation	0.60	0.41
	Planting	10.00	6.88
	Labour saving	10.90	7.50
	Crop Nutrition	14.73	10.13
	In crop pest and weed control	0.6	0.41
	Storing vegetables	20.00	13.75
	Regulatory compliance	0.73	0.50
		57.55	**39.58**

The cropping sectors were all estimated to experience significant proportional increases in GVP with sugar being the lowest (23%) and grains the highest (51%). Cropping enterprises are generally more input intensive, and are high cost of production businesses so it is to be expected that the multiplier effects of equivalent boosts in on-farm productivity will result in larger impacts on GVP compared to other sectors.

Export focused sectors such as grains however, were estimated to have a much lower follow through impact on GDP. This is because most of the productivity increases in the grains industry would result in greater exports with no additional value adding or processing. Horticulture GVP increase on the other hand was estimated to have a much bigger impact on GDP because most horticultural produce is either consumed domestically or is processed with value added for export.

The grains sector was estimated to achieve a much larger proportional benefit than rice, cotton or sugar due to larger productivity improvement assumptions. For the purposes of this project the commodity groupings have been consistent with the RDC structure. The grains sector therefore consists of many different crops while rice, cotton and sugar have been modelled as single enterprises. One of the main estimated gains to productivity for the grains sector that may be achieved through decision agriculture is the ability of farmers to use data to make decisions about the most profitable cropping sequence to implement.

Improvements in productivity through crop sequencing and planting decisions account for the higher estimated increase in GVP for the grains sector compared to rice and cotton. Once the crop has been planted the GVP benefits for all the cropping sectors was similar.

Sugar was estimated to have a slightly lower proportional benefit to GVP due to the lower amount of intervention opportunities available in the sugar cropping system compared to annual crops.

The high proportional increase in GVP estimated for horticulture was partially due to a projected post-harvest impact due to data being used to better inform farmers of product quality resulting in less loss during storage, handling and transport (a significant cost in the horticultural sector).

Animal Sector

Table 3.3 displays the productivity shocks that were modelled for the animal sectors and the corresponding impact on GVP.

Table 3.3 Productivity shocks and corresponding increase in GVP for the animal sectors

Sector	Practice	Productivity improvement modelled (%)	Increase in GVP (%)
Beef	Breeding decisions	12.99	6.33
	Feed, landscape and water management	11.99	5.84
	Animal health and disease monitoring	5.00	2.43
	Labour saving	3.17	1.54
		33.15	**16.14**
Sheepmeat	Breeding decisions	13.00	5.92
	Feed, landscape and water management	12.00	5.47
	Animal health and disease monitoring	10.00	4.55
	Labour saving	2.93	1.33
		37.93	**17.28**
Pork	Animal health monitoring	5.00	0.72
	Inefficient feed systems	5.44	0.78
	Automation	1.80	0.26
	Processing efficiencies	3.00	0.43
	Feed conversion improvement	20.00	2.87
		35.25	**5.05**
Wool	Breeding decisions	10.00	4.66
	Feed, landscape and water management	10.00	4.66
	Animal health and disease monitoring	10.00	4.66
	Labour saving	2.99	1.39
	Generic product marketing	5.00	2.33
		37.99	**17.71**
Dairy	Breeding decisions	10.00	4.63
	Pasture management	10.00	4.63
	Automation	6.64	3.08
	Animal health monitoring	5.00	2.31
	Regulatory compliance	0.44	0.21
		32.09	**14.85**

A consistent proportional increase in GVP was estimated across all the animal sectors, except for pork. This difference is explained by industry structural considerations rather than a difference in the potential for the on-farm application of decision agriculture.

Increases in productivity for beef, sheepmeat, wool and dairy can all result in increases in product available for export. Pork on the other hand does not have strong export markets so increases in production need to be consumed domestically. This would likely result in lower prices and increased pork industry consolidation, consequently the GVP was not projected to increase proportionally in the same way as was the case for the other animal sectors. The potential for decision agriculture in the pork industry can still be observed in GDP impact however, as the proportional increase (as a percentage of baseline GVP) is similar to the other animal sectors.

It is important to note that an estimated smaller proportional increase in GVP for the animal sectors compared to crops does not mean that there would be less opportunity for decision agriculture in the animal sectors generally. Most of the impact achieved through decision agriculture for the animal sectors was estimated to be achieved through better understanding of genetics and management to achieve productivity gain. In other words, there is a lot of improvement that can be achieved without fundamental changes to input rates or capital requirements.

The estimated overall productivity shock that was modelled for the beef sector, for instance, was 33% compared to 17% for grains. Grains, however, was estimated to achieve a GVP increase of 51% compared to16% for beef. Consequently, while the on-farm opportunity was estimated to be similar or even slightly higher for beef, because beef needs to be further processed for consumption or exports, some of the benefits of on-farm productivity improvement have to be passed to processers to induce more processing (evidenced by higher GDP, *Table 3.1).* By contrast, cropping products can be directly exported (eg wheat) or consumed (eg vegetables) without further processing, so the benefits of farming productivity are mainly kept on farm.

Because all the animal sectors have significant post-farm processing activity required before their product can be consumed or exported, the estimated impact on GDP of increased output was higher.

For the dairy sector, the estimated GVP increase is only that which was related directly to on-farm activities and does not include flow through productivity improvements to the milk processing sector, which would be significant.

Vertically Integrated Industries

Table 3.4 displays the productivity shocks that were modelled for the vertically integrated sectors and the corresponding impact on GVP.

Table 3.4 Productivity shocks and corresponding increase in GVP for the vertically integrated sectors

Sector	Practice	Productivity improvement modelled (%)	Increase in GVP (%)
Egg	Animal health monitoring	3.00	0.45
	Nutrition management	3.15	0.47
	Shed monitoring	1.58	0.24
	Labour saving	1.90	0.29
	Product marketing	5.00	0.75
		14.62	**2.20**
Chicken Meat	Animal health monitoring	3.00	0.44
	Nutrition management	3.14	0.46
	Shed monitoring	1.58	0.23
	Labour saving	1.90	0.28
	Product marketing	5.00	0.74
		14.61	**2.16**
Wine	Planting	10.00	1.31
	Pruning	10.00	1.31
	Irrigation and nutrient application	10.00	1.31
	Labour saving	2.65	0.35
	Grape harvest	10.00	1.31
	Consumables management	3.30	5.11
	Harvesting and winemaking logistics	0.86	1.34
		46.81	**12.04**
Forestry	Site selection	4.00	0.66
	Disease and pest control	5.00	0.82
	Pruning and thinning	4.00	0.66
	Labour saving	5.15	0.85
	Processing logs for timber	30.00	27.60
	Labour saving	7.04	6.48
		55.19	**37.07**

The highly vertically integrated nature of businesses that dominate the egg, chicken meat, wine, and forestry industries, make it difficult to distinguish pre-farmgate and post-farmgate activities. For example, chicken meat processors own the chickens throughout the production process with chicken growers being paid a grower fee; and in the wine industry, while there are many smaller independent growers, very large wine businesses that grow the grapes and make and market the wine also exist. Therefore, modelling for these industries included the downstream activity of egg and poultry meat processing, wine making and paper and wood product manufacturing.

The estimated benefits arising from downstream activity were much more significant than pre-farmgate activity for all industries, the primary reasons for which, varied for each industry.

The poultry industry structure involves chicken farmers as contracted growers achieving relatively fixed margins, meaning that the chicken owners (the processing companies) are estimated to realise most of the productivity improvements achievable as a result of decision agriculture.

In the wine industry one of the biggest gains from decision agriculture include the improved forecasting of wine quantity and quality resulting in more efficient wine making processes and better control of costs associated with consumables required.

The forestry industry has a unique set of circumstances related to the time-lines associated with growing timber. There are very few intervention possibilities during the growing stage due to the length of time required for trees to mature, however there are estimated to be large efficiency gains available in the processing stage when wood is converted to timber.

Live Export, Red Meat Processing and Fisheries

Table 3.5 displays the productivity shocks that were modelled for the live export, red meat processing and fisheries sectors and the corresponding impact on GVP.

Table 3.5 Productivity shocks and corresponding increase in GVP for the live export, red meat processing and fisheries sectors

Sector	Practice	Productivity improvement modelled	Increase in GVP (%)
Livestock export	Transport and logistics	1.11	0.97
	Animal health monitoring	2.00	1.75
	Regulatory compliance	2.00	1.75
		5.11	**4.48**
Red meat processing	Livestock sourcing and assessment	2.00	1.93
	Labour saving	2.86	2.76
	Carcase utilisation	3.00	2.89
	Marketing	5.00	4.82
	Regulatory compliance	2.00	1.93
		14.86	**14.32**
Fisheries and Aquaculture	Catching fish allowed under quota	30.00	33.24
	Operating boats at sea	5.00	5.54
	Labour saving	4.30	4.76
		39.30	**43.54**

While there is certainly scope for the use of decision agriculture technology in the live export industry, the small amount of activities that make up the industry mean that there is limited ability to make fundamental and significant improvements resulting in a boost to the economy. The live export industry is fundamentally a logistics business with the added requirement of maintaining high animal welfare standards. Estimated improvements for the live export industry arising from decision agriculture were limited to improvements in transport efficiency and animal health and welfare.

Red Meat Processing

The red meat processing sector is estimated to benefit from decision agriculture in multiple ways. Direct efficiency gains through process automation are relatively straightforward however additional gains will be made by using the same carcase data that is captured as part of the automation process for other activities such as improving marketing e.g. connecting eating quality and provenance information.

Fisheries and aquaculture

The fisheries and aquaculture industry was estimated to achieve one of the highest proportional increases in GVP modelled. Almost all of this increase was estimated to arise from the productivity boost that would be achieved from catching allowable quota in less time with reduced cost. While this seemed like a relatively simple shock to model, the practical barriers to achieving this are considerable and are detailed in the sectoral analysis (*Appendix 2*).

Common Themes for Productivity and Profitability Improvement From Decision Agriculture

There were several common cross-industry themes that emerged during the data collection and consultation phase of this project.

Optimising input use through variable rate technologies and practices

The application of variable rate technology (VRT) to increase productivity is an opportunity common to most agricultural sectors. Requiring a combination of both spatial and temporal data from a range of different data sources, VRTs are a management tool aimed at reducing the variability of production through space and time. For example, in-field variability can be managed by providing a mechanism through which the application of inputs (e.g. fertiliser, seed, water) can be altered based on calculations using a combination of data sources.

VRT is well advanced in some of the broadacre cropping sectors, such as cotton and grains, however the modelling suggests the scope for significant further improvement is large. In the livestock sectors, there is strong interest in applying the principles of variable rate management to individual animal and pasture management.

While VRT can extend beyond nutrient application to pesticides, fungicides and other inputs, improving nutrient use (in grains and livestock sectors) is still the most common application of this technology. Table 3.6 displays the size of the opportunity that the modelling has estimated would be achieved across sectors through decision agriculture for better crop and pasture nutrition.

Table 3.6 Cross sectoral boost to GVP from better crop and pasture nutrition

Sector	Practice	GVP $ Million	Productivity improvement modelled (%)	Increase in GVP (%)
Rice	Crop Nutrition	11.8	1.62	4.57
Grains	Crop nutrition	1000.1	2.85	8.68
Cotton	Crop Nutrition	99.3	11.66	7.03
Sugar	Crop nutrition	97.6	17.72	7.76
Horticulture	Crop Nutrition	103.1	14.73	10.13
Beef	Feed, landscape and water management	610.8	11.99	5.84
Sheepmeat	Feed, landscape and water management	163.3	12	5.47
Wool	Feed, landscape and water management	118.9	10	4.66
Wine	Irrigation and nutrient application	76.8	10	1.31
Total		**2282**		

Timely decision-making through real-time monitoring systems (e.g. remote and proximal sensors)

One of the key premises of decision agriculture is to make decisions based on up-to-date information. Digital technologies such as sensors have the potential to enable real-time monitoring of production conditions e.g. crop status or livestock health. When aggregated and analysed, the information generated from sensors can facilitate the early intervention and management of issues before they have a major impact e.g. sub-clinical detection of animal health conditions.

Increased process automation and labour savings

Labour is one of the most significant costs for most agricultural enterprises. There is a clear value proposition for farmers to adopt technologies which increases labour efficiency. The impact of digital technologies on labour efficiency is likely to be the greatest in sectors that have routine tasks with a high degree of predictability and that need to be performed with a high degree of accuracy.

Process automation, where sensors replace subjective human assessment of such things as animal health, will result in both labour efficiency being increased as well as more accurate measurement leading to increase in productivity.

An important part of the value proposition for adopting labour saving technologies will be improved workplace health and safety. For example, in the red meat processing sector the combination of objective carcase measurement and robotics could increase the accuracy of cutting while reducing product wastage and improving workplace health and safety.

One of the most common areas of labour saving across sectors will be the use of digital technologies for regulatory and compliance requirements. Meeting market and regulatory requirements is a major cost for many producers. In some sectors, such as the livestock export industry, the regulatory burden has increased substantially in recent years. A common concern from producers across a range of industries is that there is unnecessary duplication in compliance schemes and an over-reliance on traditional paper-based reporting. Digital systems provide alternative ways of meeting information and compliance requirements more efficiently, through the potential to automate data collection and reporting and replace time-consuming manual reporting processes, which would satisfy the need to 'make life easier for producers'.

Table 3.7 displays the size of the opportunity estimated by the modelling that may be achieved through process automation and labour savings across sectors.

Table 3.7 Cross sectoral boost to GVP from process automation and labour saving

Sector	Practice	GVP $ Million	Productivity improvement modelled (%)	Increase in GVP (%)
Rice	Irrigation scheduling and application	38.9	5.32	15
Rice	Labour saving	17.8	2.44	6.86
Grains	Labour saving	878.0	2.5	7.62
Cotton	Irrigation scheduling and application	144.8	17	10.25
Cotton	Labour saving	33.1	3.88	2.34
Sugar	Labour saving	23.1	4.2	1.84
Horticulture	Labour saving	76.3	10.9	7.5
Beef	Labour saving	161.3	3.17	1.54
Sheepmeat	Labour saving	39.9	2.93	1.33
Pork	Inefficient feed systems	8.5	5.44	0.78
Pork	Labour saving	2.8	1.8	0.26
Wool	Labour saving	35.5	2.99	1.39
Dairy	Labour saving	102.8	6.64	3.08
Egg	Shed monitoring	20.7	1.63	0.24
Egg	Labour saving	24.9	1.96	0.29
Chicken Meat	Shed monitoring	58.9	1.63	0.23
Chicken Meat	Labour saving	69.5	1.95	0.28
Wine	Labour saving	20.3	2.65	0.35
Forestry	Labour saving	126.6	5.15	0.85
Forestry	Processing logs for timber	4102.8	30	27.6
Forestry	Labour saving	962.9	7.04	6.48
Red meat processing	Labour saving	400.4	2.86	2.76
Fisheries and aquaculture	Labour saving	101.5	4.3	4.76
Total		**7363**		

Accelerating genetic gains through objective data

In recent decades, there have been major improvements in plant and animal genetics using genetic benchmarking and genomics tools. Data analytics has the potential to accelerate these methods by integrating this information with performance data from other sources such as insights that link genetic, production and processing data. For example, there are potentially significant opportunities to increase the productivity of the livestock industries through integrating genetic and genomic data, with lifetime productivity information (e.g. weight gain, health status), and objective carcase feedback.

Even without further genetic gain, decision agriculture provides the capability through the assessment of objective data to select the most appropriate existing genetics or even make fundamental changes to cropping sequences or animal breeds for increased productivity and profitability.

Table 3.8 displays the opportunity estimated by the modelling that may be achieved through better breeding, genetic selection and rotation decisions as a result of the application of decision agriculture.

Table 3.8 Cross sectoral boost to GVP from better breeding, genetic and rotation decisions.

Sector	Practice	GVP $ Million	Productivity improvement modelled (%)	Increase in GVP (%)
Grains	Crop rotation	1756.0	**5**	15.24
Sugar	Crop rotation	55.1	10	4.38
Beef	Breeding decisions	661.7	12.99	6.33
Sheepmeat	Breeding decisions	176.9	13	5.92
Wool	Breeding decisions	118.9	10	4.66
Dairy	Breeding decisions	154.8	10	4.63
Total		**2923**		

Improving market access through improved traceability and product assurance

Throughout the consultation phase of this project, decision agriculture was universally acknowledged as being important for the development of traceability and provenance platforms. Digital traceability and provenance systems are becoming increasingly important in maintaining and developing new high-value markets, and providing confidence for end users (and consumers) in product safety and quality.

‘Push' and 'pull' factors influence how traceability and product quality assurance systems are used in different agricultural value chains. Push factors include regulatory compliance issues such as industry-wide food safety programs, which are regulated by government. Pull factors include certification programs which offer market premiums for products that meet certain specifications. In some cases, push and pull factors may occur simultaneously, and in all cases data plays a critical role in validating provenance claims.

While the economic impact of traceability and provenance platforms was not modelled, the consensus from every sector was that it would be one of the most valuable benefits realised from decision agriculture.

Strengthening biosecurity systems

Biosecurity is a significant challenge for Australia's agricultural industries. Biosecurity monitoring platforms are critical for preventing the spread of pests and disease, and therefore the maintenance of markets and market access.

Digital biosecurity platforms (manual and automated) provide the potential to act as integrated management systems to mitigate the threat of biosecurity breaches. Due to the complexity associated with measuring the economic impact of biosecurity incursions, the potential economic benefit was not modelled. However, as with traceability and provenance systems, the consensus from every sector was that the platforms developed to enable decision agriculture would enable better biosecurity monitoring. While not resulting in an immediate economic benefit, the potential to stop an economic catastrophe in an industry or multiple industries was perceived to be significant.

An immediate economic benefit will be realised from the improved management resulting from the data collected as part of broader biosecurity efforts. For example, the animal health monitoring that is required to monitor for disease outbreaks is just as useful for measuring the performance and efficiency of animals for productivity and profitability gain. Likewise, in cropping sectors, monitoring for pest and disease is required for managing the crops productive potential, but it is also the same information that can be used to track incursions of exotic pests and disease.

Table 3.9 displays the opportunity estimated by the modelling that may be achieved through management platforms that also form part of broader biosecurity efforts.

Sector	Practice	GVP $ Million	Productivity improvement modelled (%)	Increase in GVP (%)
Rice	Fallow Weed Control	7.5	1.03	2.9
Rice	In crop weed and pest control	2.0	0.28	0.79
Grains	Crop protection and Weed control	91.0	0.26	0.79
Cotton	Crop Protection and Weed Control	13.4	1.57	0.95
Sugar	Crop protection and weed control	9.5	1.74	0.76
Horticulture	In crop weed and pest control	4.2	0.6	0.41
Beef	Animal health and disease monitoring	254.7	5	2.43
Sheepmeat	Animal health and disease monitoring	136.1	10	4.55
Pork	Animal health monitoring	7.8	5	0.72
Wool	Animal health and disease monitoring	118.9	10	4.66
Dairy	Animal health monitoring	77.4	5	2.31
Egg	Animal health monitoring	38.1	3	0.45
Chicken Meat	Animal health monitoring	106.8	3	0.44
Forestry	Disease and pest control	122.6	5	0.82
Livestock export	Animal health monitoring	28.1	2	1.75
Total		**1018**		

Summary

Decision agriculture has been estimated to deliver a substantial benefit to Australian agriculture and to the broader economy. All sectors will benefit from decision agriculture however structural issues related to export opportunities or the extent of vertical integration will have an impact on which part of the value chain will benefit most from the technology.

The next section of this report looks at the business models for product and service delivery that will deliver the benefit described in this section.

Business and Service Delivery Models for Decision Agriculture

This section presents the project’s key findings about the business models (and their value propositions) that are likely to support the further development of decision agriculture in Australia.

One of the main purposes of the P2D program is to identify a strong business case and value proposition for decision agriculture. This project investigates the likely business and service delivery models that will develop decision agriculture products and services.

Currently, the development and uptake of decision agriculture has been underwhelming compared to the associated hype. The report considers international experiences in digital agriculture, with a particular focus on the US and Europe. Digital agriculture and related big data applications are more advanced in the cropping sector of the US than is the case in Australia, and are generally more developed in the cropping sectors than in the livestock sectors. In some Australian sectors, there is potential for the international spillover of technologies from other regions.

This section is structured into two main parts:

- Background and Context – This includes a review of literature on business models and value propositions, the 'lean' and 'agile' approach to business development, and generic business models used in digital agriculture.
- Key Findings – This includes a summary of the current state and likely future development of digital agriculture product service delivery for Australian agriculture. As part of this, the report discusses the potential international spillover of digital agriculture products and services into Australia.

Background and Context

> *… Business models are less durable than they used to be. The basic rules of the game for creating and capturing economic value were once fixed in place for years, even decades, as companies tried to execute the same business models better than their competitors did. But now, business models are subject to rapid displacement, disruption, and, in extreme cases, outright destruction* (de Jong & van Dijk, 2015).

The combination of several technological, social and business trends is changing the way businesses in all sectors of the economy operate. We are witnessing the rise of digital entrepreneurs and the proliferation of start-ups, driven in part by changes to the financial sector (e.g. private equity trends). This is leading to digital disruption and the rise of new players who are challenging traditional business models (think Uber in the taxi industry or

Airbnb in the hotel industry). The ubiquity of digital technology is leading to the emergence of new business models in agriculture and the development of an AgTech[1] sector.

Developing a business model

A business model is essentially a plan for the successful operation of a business. A clear value proposition is an essential part of a business model. According to Chesbrough (2003) there are six elements a business model must encompass:

1. Articulate the value proposition – that is, the value created for users by the offering.
2. Identify a market segment – that is, the users to whom the offering and its purpose are useful.
3. Define the structure of the value chain required by the firm to create and distribute the offering, and determine the complementary assets needed to support the firm's position in this chain (this includes the firms' suppliers and customers and should extend from raw materials to the final customer).
4. Specify the revenue generation mechanisms for the firm, and estimate the cost structure and profit potential of producing the offering, given the value proposition and value chain structure chosen.
5. Describe the position of the firm within the value network (also referred to as the 'ecosystem'), linking suppliers and customers, including identification of potential 'complementors' (e.g. third-party software providers) and competitors.
6. Formulate the competitive strategy by which the innovating firm will gain and hold an advantage over rivals.

The Business Model Canvas is a template for developing new or documenting existing business models that has becoming widely used over the past decade. It was first proposed by Alexander Osterwalder (2008) to provide a single reference point for business model development. The model covers key building blocks of a business, including areas such as infrastructure, offering, customers, finances, and resources (*Table 4.1*).

[1] The term decision agriculture has been used throughout this report to describe a specific set of digital technologies and the purpose of their use. In the investment community, the technologies that are involved in decision agriculture are often described as AgTech.

Table 4.1 The Business Model CANVAS. (Source: Ge et al. 2016)

<table>
<tr>
<td rowspan="2">Key Partners

The essential strategic and cooperative partnerships.</td>
<td>Key Activities

The most important activities in executing a company's value proposition.</td>
<td rowspan="2">Value Proposition

An analysis or statement of the combination of goods and services offered by a company to its customers in exchange for payment.</td>
<td>Customer Relationships

The development of an on-going connection between a company and its customers. These relationships are established and maintained with each customer segment.</td>
<td rowspan="2">Customer Segments

The separation of a group of clients into sets of similar individuals that are related from a marketing or demographic perspective.</td>
</tr>
<tr>
<td>Key Resources

The resources necessary to create value for the customer. They are considered an asset to a company, which are needed in order to sustain and support the business.</td>
<td>Marketing Channels

Touchpoints used by a company to market its products or services to customers. Channels include communication, distribution and sales channels.</td>
</tr>
<tr>
<td colspan="2">Cost Structure

The costs that are associated with each of the above element.</td>
<td colspan="3">Revenue Stream

The income generated from the sale of goods or services, or any other use of capital or assets, associated with the main operations of an organisation.</td>
</tr>
</table>

Business strategy mistakes to avoid

The digital revolution is changing the ways businesses operate in a range of industries. According to Porter and Heppelmann (2014) of the Harvard Business School, there are a number of common business strategy mistakes that technology firms tend to make, including:

- **Adding functionality that customers don't want to pay for.** Just because a technological feature is now possible it does not mean there is a clear value proposition for the customer. Adding enhanced capabilities and options can reach the point of diminishing returns, due to the cost and complexity of use.
- **Underestimating security and privacy risks.** Smart, connected products open new gateways to corporate systems and data, requiring stepped-up network security, device and sensor security, and information encryption. In addition, this is leading to the rise of legal and trust issues.
- **Failing to anticipate new competitive threats.** New competitors offering products with smart, connected capabilities (such as embedded software) or service-based business models can emerge quickly and reshape competition and industry boundaries.
- **Waiting too long to get started.** Moving slowly enables competitors and new entrants to gain a foothold in a market and develop data analytics capabilities.
- **Overestimating internal capabilities.** The shift to smart, connected products will demand new technologies, skills, and processes throughout the value chain (for example, big data analytics, systems engineering, and software application

development). A realistic assessment about which capabilities should be developed in-house and which should be developed by new partners is crucial.

The 'Lean' and 'Agile' approach to business development

> *"One of the critical differences is that while existing companies execute a business model, start-ups look for one. This distinction is at the heart of the lean start-up approach." (Blank, 2013)*

The lean methodology has been one of the defining features of the rise of entrepreneurial start-up initiatives in the past ten years. Identifying a suitable business model and getting feedback on the business' value proposition are key features of this approach. According to successful entrepreneur and start-up educator Steve Blank there are three main principles of the lean method:

1. Instead of building an intricate business plan the company summarise their hypotheses in the **Business Model Canvas** framework – a diagram of how a company creates value for itself and its customers.
2. **Customer development to test their hypotheses**. The company goes out and asks potential users, purchasers, and partners for feedback on all elements of the business model, including product features, pricing, distribution channels, and marketing strategies. The emphasis is on nimbleness and speed: new ventures rapidly assemble minimum viable products and seek immediate customer feedback. Then, using customers' input to revise their assumptions, they start the cycle over again, testing redesigned offerings and making further small adjustments (iterations) or more substantive one (pivots) to ideas that aren't working.
3. **The company practices agile development**, which originated in the software industry. Instead of long development cycles that presuppose knowledge of customers' problems and product needs, agile development eliminates wasted time and resources by developing the product iteratively and incrementally. It's the process by which start-ups create the 'minimum viable product' they test.

In summary, the lean approach to business development places a strong emphasis on the importance of iterative processes. A firm's value proposition, product/ service offering, and business model are expected to undergo a series of iterations based on customer feedback. The 'agility' to 'pivot' towards new opportunities is a hallmark of the lean approach. For example, if customer feedback reveals that a firm's business hypotheses are wrong, it either revises them or 'pivots' to new hypotheses.

Blank (2013) suggests there are two key phases of the lean approach to business development: 'The Search' – covering customer discovery and customer validation, and 'Execution' – encompassing customer creation and company building (*Figure 4.2*).

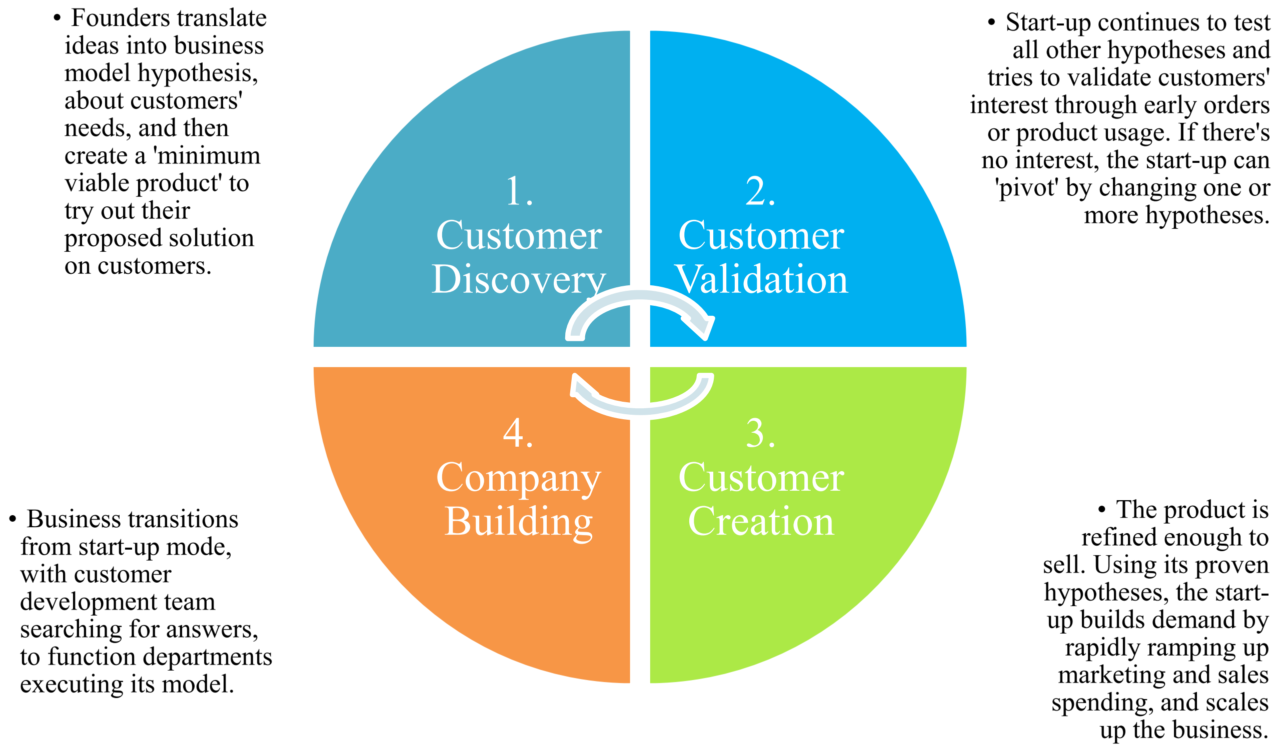


Figure 4.2 Key stages in the Lean approach to business development.

The rise in activity in the start-up sector across all areas of the economy has been driven by technological developments and changes to the financial sector. According to Blank (2013), in the past, the growth in the number of start-ups was constrained by five factors in addition to the failure rate:

1. The high cost of getting the first customer and the even higher cost of getting the product wrong.
2. Long technology development cycles.
3. The limited number of people with an appetite for the risks inherent in founding or working at a start-up.
4. The structure of the venture capital industry, in which a small number of firms each needed to invest big sums in a handful of start-ups to have a chance at significant returns.
5. The concentration of real expertise in how to build start-ups (i.e. geographic entrepreneurial hot spots).

The lean approach reduces the first two constraints by helping new ventures launch products that customers actually want, far more quickly and cheaply than traditional methods, and the third by making start-ups less risky. In addition, it has emerged at a time when other business technology trends are likewise breaking down the barriers to start-up formation. The combination of all these forces is altering the entrepreneurial landscape.

In summary, the lean approach differs from traditional approaches to business development because it favours experimentation and agility over elaborate planning, customer feedback over intuition, and iterative design over traditional 'big design up front' development (Blank, 2013). Lean start-ups move quickly and to some degree expect failure, realising that they must continually assess the value proposition they offer customers. Further key differences between these approaches is outlined in *Table 4.2* below.

Table 4.2 Characteristics of the lean vs traditional approaches. (Source: Blank, 2013)

Lean	Traditional
Strategy	
• Business Model • Hypothesis-driven	• Business Plan • Implementation-driven
New-Product Process	
• Customer Development • Get out of the office and test hypotheses	• Product Management • Prepare offering for market following a linear, step-by-step plan
Engineering	
• Agile Development • Build the product iteratively and incrementally	• Agile or Waterfall Development • Build the product iteratively, or fully specify the product before building it
Organisation	
• Customer and Agile Development Teams • Hire for learning, nimbleness, speed	• Business Departments structured by function • Hire for experience and ability to execute
Financial Reporting	
• Metrics That Matter • Customer acquisition cost, lifetime customer value, churn, viralness	• Accounting • Income statement, balance sheet, cash flow statement
Failure	
• Expected • Fix by iterating on ideas and pivoting away from ones that don't work	• Exception • Fix by firing executives
Speed	
• Rapid • Operates on good-enough data	• Measured • Operates on complete data

Business Models used to profit from Big Data

In the past decade, there has been a proliferation of new business models used by companies to provide innovative digital products and services. Developments have occurred in a range sectors, including retail, and logistics and transport, with potential implications for agricultural supply chains. Implications for agriculture will also be derived from the rise of e-commerce, digital advertising, social media and the 'sharing economy'.

The Boston Consulting Group (BCG) has investigated how companies have sought to build new business models around big data products and services. Their conceptual framework explores two core dimensions of a business model:

1. The product/ service delivery method, which differs in the degree of personalisation offered to customers; and
2. The revenue source, which varies according to the duration of the relationship between business and customer.

Figure 4.3 illustrates the seven generic business models for profiting from Big Data, with examples relevant to the AgTech sector.

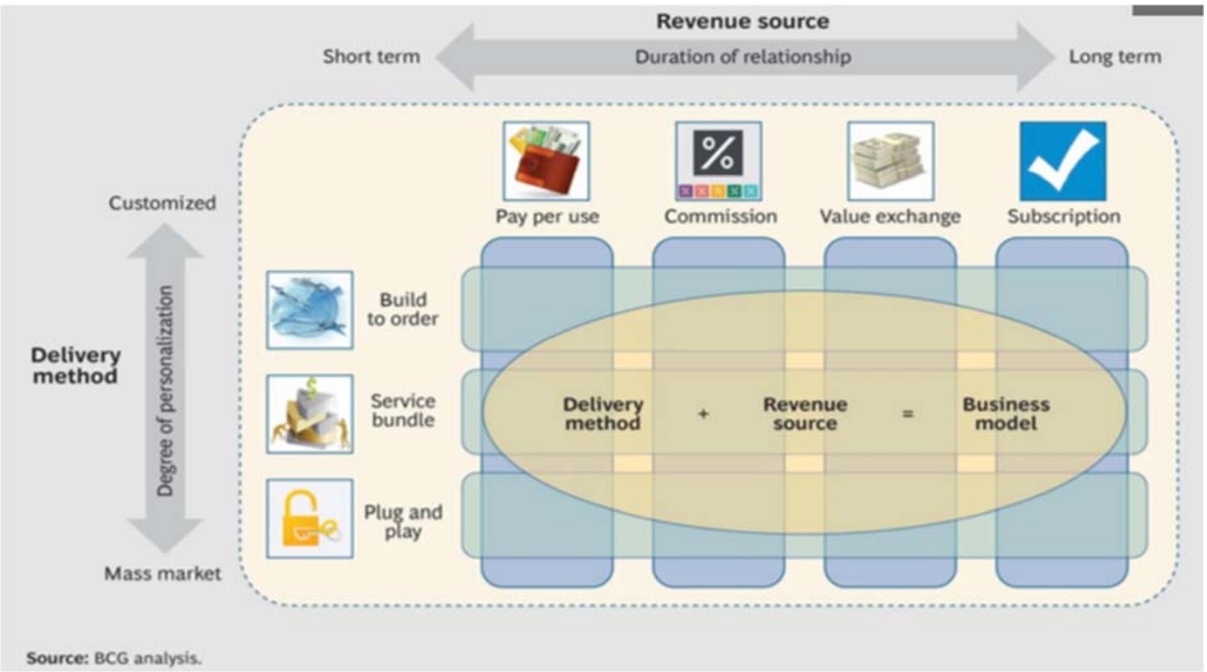


Figure 4.3 Seven ways to profit from Big Data as a business. (Source: BCG, 2014)

Build to Order. Tailored products and services configured to the customer's specifications. This may increase customer satisfaction and perceived value, while a high degree of specialisation can create barriers to new entrants. On the downside, customers may have to wait longer to obtain customised products or services, which are also often difficult to resell. Decision agriculture example: A large meat processing plant orders a robotic carcase splitting machine from a specialist technology provider, who customise the product to fit within the plant's existing infrastructure.

Service bundle. In this model, several offerings are combined into a single offering. Bundling can be profitable, drive rivals from the market, and create opportunities to cross-sell or up-sell existing products. However, once products and services have been bundled, it can be difficult to separate them and hard for customers to assess the value of each component of the offering. Decision agriculture example: An agribusiness automatically sourcing and supplying a grower inputs based on associated agronomic advice through a digital platform.

Plug and Play. Here, the same product is sold to every buyer. Such offerings can be easy to deliver, lend themselves to discounting strategies, and increase margins through economies of scale. But customers may consider them to be of lower value than build-to-order products because of the lack of personalisation, and their transactional nature can increase the risk that customers will switch to a competitor. Decision agriculture example: A machinery company (e.g. John Deere) sells advanced data collection tools embedded in all new machinery.

The other four business models differ in terms of the duration of the relationship with the customer, from short-term to long-term.

Pay per Use. This option gives customers easy access to a wide selection of offerings, but they only pay for what they use. While it offers improved margins compared with subscriptions (discussed below), this business model does not create a stable source of revenue, and the sometimes high-cost of customer acquisition must be factored into the profit equation. Decision agriculture example: Farmers buy satellite imagery on a per image basis.

Commission. This business model is exemplified by a bank that analyses credit card transactions and offers discounts to stores and restaurants that agree to pay a fee, usually based on the revenue generated. The relationship is generally stronger and longer lasting than one associated with the pay-per-use model, because of the ongoing nature of the revenue-sharing arrangement. However, a high degree of variation can creep into the offering. Companies must also consistently add value in order to increase the fees that customers pay. Decision agriculture example: A grains producer pays a commission for using an online platform for blending parcels of grain in order to achieve a higher price.

Value Exchange. In this model, a partner standing between the company and the customer offers some kind of rebate, discount, or additional service, depending on the business. For example, a bank could offer a merchant discount brokered by an intermediary, creating cash back to the customer upon completion of the transaction. Value is generated in the form of a commission paid to the partner by the company and the monetary benefit delivered by the company to the customer. By targeting only customers of interest, the company improves the return on its marketing investment, but the presence of an intermediary that captures value from the customer may be a long-term disadvantage. Decision agriculture example: A third-party sales agent is paid a commission by a farm input supplier for selling their product on an online platform.

Subscription. With subscriptions, the customer pays a periodic fee for unlimited access to a service over a set period. The subscription model ensures a predictable revenue stream with good potential for up-selling and cross-selling of additional products or services. The downside is lower margins than those typically generated by the pay-per-use model. Decision agriculture example: A farmer subscribes to a platform that aggregates and analyses multi-farm data for benchmarking purpose.

In practice, combinations of business models are increasingly being used by companies seeking to offer customers a unique value proposition. For example, the following combinations:

- Plug and Play + Subscription – A farmer purchases a new John Deere tractor and also subscribes to JD Link, which provides information on equipment use (e.g. fuel use, maintenance tracking).
- Service Bundle + Commission – An agronomy services company provides advice to a farmer and receives a commission tied to crop performance.
- Build to Order + Subscription/ Pay per Use – A technology company sells a customised drone to a horticulture producer and offers customer service and repairs based on a subscription or pay-per-use arrangement.

Key Findings

The Current State of Digital Agriculture Product and Service Delivery for Australian Agriculture

The Australian market for digital agriculture products and services is in its relative infancy compared to the scale and pace of developments occurring in other parts of the world, notably the US and Israel. However, the transformation of the Australian agriculture sector into a smart, high-tech industry is showing strong signs of interest and growth. Increasingly, investors and technology developers not traditionally associated with agriculture are recognising the opportunities associated with decision agriculture. As a consequence, the Australian AgTech market is rapidly expanding, with new business models emerging and successful Australian start-ups positioning themselves to benefit from global market opportunities.

There are a broad range of data-driven applications and support tools that help guide production decisions using real-time data. This includes supporting decision-making in areas such as nutrient requirements, land use, animal health, climate risks, water efficiency and other production related factors. Products available to farmers extend from general operational and business support systems to more complex and specific, data intensive tools that use algorithms to generate quantitative information (i.e. prescriptive analytics). Decision support tools generate data and provide information for producers to help solve practical problems and help assess outcomes in a risky farming environment. The challenge for developers is ensuring products are relevant to farmers' needs, simple and easy to use, and perhaps most importantly, deliver a return on investment.

Appendix 3 presents an extensive review of decision agriculture products currently available in Australia, classified by sector grouping and product/ service category. The review highlights several key themes and trends:

Business Models

The Australian AgTech market is characterised by a strong presence of foreign innovation, with farmers seeking technology developed offshore, particularly from the US. Dyer (2015), recognises that applying new internationally developed products in an Australian context will initially be a challenge, however committed research into their application will help prove their suitability in Australia. There is likely to be a continued focus on seeking adoptable solutions from overseas.

There is also a large amount of private sector interest and investment from both large multinational well established firms as well as smaller entities. Private investors are delivering products across all major agricultural sectors and have a particularly strong presence in delivering general farm business and finance packages e.g. the John Deere Operations Centre (international) and Phoenix by AGDATA (Australian).

The Australian AgTech sector has delivered many products resulting from public/private partnerships. Partnerships have the benefit of using different Government, corporate and industry bodies in the research, product development and funding process. Collaboration will remain important in establishing the most appropriate agriculture technology. Some examples include;

- CropPro: diagnostic tool to identify crop problems developed by GRDC and the Department of Environment and Primary Industries (DEPI) Victoria.
- SoilMapp (App): decision support tool providing information on soil characteristics from Australia's national soil database. Developed by the CSIRO through a joint project with the Australian Collaborative Land Evaluation Program and GRDC.
- Weed Seed Wizard: predictive tool to manage weed emergence in a range of crops across Australia, assesses how different management and harvesting practices affect weed numbers and yield. It is a collaboration between DAFWA, GRDC, University of Western Australia, University of Adelaide, NSW DPI, QLD Department of Agriculture, Fisheries and Forestry (QDAFF).

The RDCs have played a facilitating and supporting role, providing support throughout several partnerships and government initiatives, which have the power to drive industry awareness and adoption of decision agriculture and have participated less so in the direct creation and development of digital agriculture products.

Start-ups entering the AgTech market have increased in number reflecting the availability and access to a range of funding sources as well as accelerator and incubator programs. Successful Australian start-ups include The Yield and AgriDigital. The Yield has worked closely with the Australian oyster industry to develop the Sensing+ platform for aquaculture. Sensing+ is a microclimate sensing system to record and analyse water quality and climatic conditions. AgriDigital have developed a blockchain technology platform servicing the grains sector to provide grain provenance and payment systems.

Product delivery

AgTech innovation has taken many forms. These range from the most simple and affordable mobile applications (apps) to software technology and more sophisticated developments in the form of sensor and drone technology that collect real-time farm data across the entire farming operation.

Apps are a popular product delivery platform. The dominance of apps has grown in line with developments in smart phone and tablet technology. They are a simple and affordable option for farmers that are relatively easy to adopt. RDCs have contributed to the development of a large number of apps through partnerships with Government, universities and the private sector. Simple apps tend to be sector and issue specific providing a narrow range of solutions. Issue specific apps include;

- SoilWaterApp: generates estimates of plant available water using local rainfall records. Developed in partnership by GRDC and the University of Southern Queensland.
- PestTrack App: records presence of fruit flies in Queensland and maps out control efforts via trapping data. Developed by Advance Computing.

More complex cross-sectoral products are available that can be employed across entire farming operations, particularly in general farm business management. For example, accounting, budgeting and financial software programs have been important in assisting farmers to better understand business operations and their financial situation through the generation and analysis of key financial reports and budgets. There is a growing reliance on these products for the day to day operations of the farm business. Some digital agriculture products and services aimed at financial management include;

- P2PAgri: business analysis and reporting software with function to generate key finance reports including balance sheet, profit and loss statement, cash flow chart to aid in business planning decisions. Includes a scenario analysis tool to develop 'what if' scenarios to manage risk and potential business expansion. Developed by P2P Agri.
- PS Cashbook Standard/Connect/Premium: Farm accounting software providing budgeting tools and projections, detailed trading accounts and cash flow reports to help users better understand the state of their farming business. Developed by Practical Systems.

Sensor technology has been a strong driver of the AgTech investment environment. Sophisticated sensors and imagery have been effective across cropping and livestock sectors with improvements in livestock management and crop health observed. Sensing applications have enabled farmers to control livestock remotely and receive alerts of animal health as well as track the development of crops with field monitoring allowing for the early detection of crop disease.

Drone technology has a huge potential to be employed in a variety of applications in agriculture. To date, drones have been mostly used on a trial and testing basis with few widespread commercial applications being observed. Drones enable the capture of a wide range of data in real-time, leading to more informed on-farm decisions and providing a more relevant outlook of the current state of farm operations. Digital agriculture products and services based on drone technology include;

- FarmLens: drone technology and data service provider offering data collection and processing via Farm Lens software to produce field maps and identify areas of crop concern. Developed by Agribotix (US).
- 3D Farm Modelling: farm planning, monitoring and mapping with capacity to model weather patterns, irrigation rates and farm structures. Developed by DroneAg.

The idea of online sharing has taken root in agriculture. Sharing practices have increasingly appeared across the AgTech landscape. AgTech product developers have taken advantage of this relatively new practice with the delivery of online platforms and marketplaces making it easier to hire equipment and machinery or look for labour. Equipment sharing has been on the rise in the agricultural industry (Deloitte, 2017). Two leaders in the online sharing platform market are AgDraft and Agtribe. AgDraft enables farmers to connect to skilled rural workers, making labour hire quick and reliable. Agtribe offers an online equipment and machinery hire platform for farmers to search for farm equipment and machinery in an efficient and cost-effective manner.

Category specific findings

There are relatively more AgTech products available for the cropping sectors than the livestock sectors, reflecting the industry size, greater demand and high number of Government and industry bodies participating. The cropping sector has the added advantage that a large number of internationally developed products are commercially available in Australia.

There is limited availability of internationally developed products in the soil, water and pest management categories. This is partly due to Australia's unique soil landscape and invasive species profile. Australian agriculture is generally better suited to developing these types of products domestically rather than to adopt from overseas. Partnerships are leading the way in terms of providing a strong supply of tools related to soil characteristics, weed identification and management and feral animal sightings and numbers. For example;

- WeedSmart (App): provides simple advice on herbicide resistance and an assessment on the effectiveness of weed management practices to encourage early detection of weeds and improved weed management. Developed by GRDC.
- FeralScan: Web and app based mapping resource to record pest activity, damage and problems and report on control and prevention measures. Collaborative project with project partners including Invasive Animals CRC, PestSmart, Australian Government Department of Industry and Science, NSW Local Land Services, NSW Office of Environment and Heritage, NSW DPI, Landcare, ABARES and Australian Government Department of Environment.

Emerging products

A range of AgTech products are still in the development stage. This includes technologies available on a trial and testing basis, or that are currently in field and semi-commercial trials. The speed of technological change means that product offerings for decision agriculture will be continually changing and possibly accelerating in the near term. For example, three emerging products from Australia are:

- eShephard: Agersens has developed a neck collar and app enabling farmers to fence, move and monitor livestock using a smartphone.
- RapidAIM: delivers real-time alerts of the presence and location of fruit flies via smart traps, completion of first semi-commercial trial successful. It is projected to have traps and data packages available commercially to customers within twelve months.
- Ceres Tag: smart ear tag for identification and monitoring of livestock where information can be managed via a smartphone or app. Currently still in development stage – projected to have the product ready for market by the end of 2019 or beginning of 2020.

Australian AgTech Snapshot – Current Digital Technology Developments by Sector

Rice

According to RIRDC (2017), the rice industry has engaged in a number of change initiatives involving technologies aimed at increasing on-farm production efficiency, water use efficiency and environmental management. While profitability is recognised as a key driver of change for rice growers, social factors, ranging from growers' existing knowledge networks to the broader policy environment which influence their practices, can also act as significant barriers to, or enablers of, technology adoption. In recognition of low digital technology use in rice production, a recent RIRDC, *Social factors influencing technology adoption in the rice industry*, project investigated the social factors that influence technology adoption by rice growers.

The Ricegrowers' Association of Australia (2017) report that most of the equipment used on rice farms is fitted with computer-aided devices that allow our growers to manage their techniques with accuracy, and may include:

- **GPS (Global Positioning Systems) and Precision Farming** – Uses satellite networks to precisely match crop needs with crop requirements.
- **Computerised Whole Farm Design and Laser Landforming** – Uses computer aided design (CAD) and laser technology to design efficient farm irrigation systems. Laser landforming ensures the most efficient use of water. Farmers have precise control over the flow of water on and off the land.
- **GIS (Geographical Information Systems)** – GIS is used to organise geographical information which is then stored digitally on a database.
- **Remote Sensing** – Spectral imaging obtained from satellites and aircrafts assists with the planning and management of the farm system. Farmers can calculate the exact capabilities of their farm by identifying enterprises to suit each area.
- **Aerial Machinery** – Experienced agricultural pilots use satellite guidance technology to distribute seeds and other inputs across a rice bay with precision and accuracy.

Grains

The Australian Grains industry has been proactive in the promotion of digital technology. The most recent developments include trialling of block chain technology and real-time protein mapping technology. The huge potential of block chain technology is being tested in grains as a solution to improve payment efficiency and traceability throughout the supply chain. Currently, Australian based technology start-up, AgriDigital is participating in several block chain pilot trials in partnership with Australia's biggest grain exporter, CBH at the Blue Lake Milling oat processing facility in South Australia to track oat shipments.

Real-time protein mapping technology has delivered significant benefits to grain growers. The technology delivers key information on crop characteristics. The technology has allowed producers to understand variations across paddocks and use data to monitor protein levels, drive variable rate fertiliser application decisions and nitrogen requirements to improve crop potential. It has already generating significant profit for grain growers, enabling growers to capture protein premiums. Australian company Next Instruments have worked to develop the Cropscan3000H, a spectrometer that generates a spectra for each sample of grain. Their software system works by collecting and displaying protein, moisture and oil data which is then converted into tables, field maps, protein maps and bin averages (Clancy, Undated).

Cotton

Australia's cotton industry has placed significant effort on introducing digital technology, particularly the adoption of sensors. Water is a major limiting factor to productivity and technology has been crucial in the management of irrigation (RIRDC, 2016). Cotton growers have been quick to adopt moisture probes, sensors and other new technology for improved irrigation scheduling. Sensors collect data on water use which is then used by farmers to make changes to improve water use efficiency and monitor crops. The Rabobank 'Does sensor adoption make cents' report (Rabobank, 2017) found that sensor adoption rates vary across commodity sectors with the cotton industry having the highest rate of sensor adoption at 78%. This is a relatively high figure compared to grains, 48% and beef with a 10% adoption rate.

Two irrigation technologies available to cotton producers are CottASSIST and the IrriSAT mobile app. CottASSIST is a group of web based tools to assist with a range of cotton management decisions. The crop development tool can help to monitor and determine how a crop is performing in real-time, delivering valuable insight for irrigation decisions. IrriSAT is a weather based irrigation and benchmarking technology, using remote sensing to deliver specific crop water management information and a seven-day forecast of crop water use to assist in irrigation decisions (CRDC, 2015).

Sugar

Australia's peak sugar research and investment body, Sugar Research Australia (SRA) have a goal of accelerating the adoption of new technology and best practice. A digital vision is a part of SRA's Strategic Plan 2017/18–2021/22 (SRA, 2017), which shapes the future direction of investment and R&D. SRA have committed to developing efficient data management systems and advanced analytical methods to assess 'Big Data' sets and facilitate disruptive technology. For example, using robotics, automation, drones and sensors to reshape and renew production systems.

The SRA Strategic Plan 2017/18–2021/22 considers:

- The acceleration of disruptive 'Big Data', sensors and smart connected technologies to drive innovation in data analysis and decision-support tools.
- Other forms of technology including robotics, automation, drones, sensors and GPS to redefine production systems.
- Biotechnologies advances, the application of genomics and gene technology to improve sugarcane varieties.
- Enhancing knowledge, skills and capacity to use advanced technology.

SRA are also seeking to develop efficient data systems. This will be achieved through enhanced near infrared (NIR) technology that will provide real-time data to improve the quality of crop monitoring and in mill cane analysis as well as the identification of new and innovative production technology and processes to improve the quality of Australian raw sugar.

Horticulture (leafy greens, brassicas, carrots)

Consistent with the restructure of Australian Government Rural RD&E priorities in 2015, Horticulture Innovation Australia Limited (HIAL) developed and refined its industry priorities. Data insights and novel technologies were among investment priorities aimed at growing the capacity of the industry by driving grower and supply chain capabilities. Additional key investment areas included delivering industry and market intelligence; and improving productivity of the supply chain by discovery, development and deployment of innovative technologies that increase international and domestic competitive advantage and profitability of growers.

Following from the commitment to increased investment in new and innovative technologies to increase productivity, production efficiency and maintaining international competitiveness, recent work investigated the areas in which developments in these areas (mechanisation, automation, robotics, uniform plant architecture, genomics, and protected cropping) were likely to have the greatest on-farm impact. For example, the 2015-16 project conducted by researchers from the CSIRO, Queensland University of Technology (QUT), Australian Centre for Field Robotics (ACFR), and the Variable Rate Technology (VRT) team from the Queensland Department of agriculture and Fisheries (DAF), investigated potential applications of automation, robotics and sensing technologies in field and shed operations in:

- Automated crop health monitoring
- Autonomous weed management
- Autonomous all-purpose/adaptable platforms
- Sensor and sensing networks
- Robotic harvesting
- Packing efficiencies

Red Meat (including beef, sheepmeat, and red meat processing)

Through the ‘Digital Value Chain Strategy’ (MLA, 2016), Meat and Livestock Australia (MLA) plan to accelerate the digital future of the red meat and livestock industry. The strategy aims to enable the integration and interpretation of data generation within the livestock industry and ensure value chain stakeholders are connected through open data and generated by some of the world’s best digital technology. The strategy also hopes to develop a user-friendly data platform that will improve decision-making for both farmers and business. Dual Energy X-Ray Absorptiometry (DEXA) technology, developed by Murdoch University in Western Australia and automation and robotic company, Scott Automation has gained interest from MLA. DEXA is a measurement tool used to measure carcase composition. The technology can accurately measure and differentiate meat from fat and bone with high precision. It provides farmers with a better indication of the meat content of a carcase. At the industry level, it will help to raise meat quality standards and consistency. MLA is looking to accelerate and expand the adoption of DEXA across the entire lamb and beef sector and open up greater access to data across the value chain. Stage 1 will be a $150 Million investment with installation of the technology in up to 90 registered slaughter facilities (MLA, undated). Processors who adopt the technology as part of MLA's plan would be required to provide carcass composition information back to producers as part of a more transparent and efficient value chain (MLA, undated).

Meat Processing

Australia's meat processing peak industry council, the Australian Meat Processor Corporation (AMPC) is currently investing in processing technologies to drive innovation in product, operations, business systems, communications, export, industry collaboration and environment. The meat industry has a major requirement to automate its processes of slaughtering and meat preparation including primal cutting, sub-primal breakup and de-boning. The industry faces significant challenges associated with process automation, workplace health and safety (WH&S) risks, animal welfare, and engagement of red meat processors in the digital economy.
Current research underway by the AMPC includes:

- Robotics and automated systems applications – collaborative robots; automated meat recover; conveyors; code scanners; etc.
- Hypobaric storage – a 2017 pilot study for future storage and transport of carcases using hypobaric storage of meat provided proof-of-concept for the potential use of hypobaric containers for the transport and storage of sheep meat. Development of this concept further could allow opportunities for transport of whole chilled sheep carcases directly into wet markets in countries around the world, but particularly into the Middle East. An additional benefit will be the ageing of the meat during transit.
- Primal cut recognition.
- Localisation Software for use in Robotic Pick-and-Pack Systems.
- Wearable technologies – Wearable technologies offer the ability to sense, autonomously interpret and communicate information in a portable and unobtrusive manner, making it possible to exploit a worker's proximity, location and/or perspective in order to acquire new information about the worker, the product and/or processes in real-time at every step in the supply chain.
- DEXA technology.

Sheepmeat

Efficient sheep management, reproductive efficiency, animal welfare, parasite control and effective use of genetic technologies are key problems facing the sheep producer (Sheep CRC, 2017). Currently, industry bodies such as the Sheepmeat Council of Australia, Sheep CRC and Australian Wool Innovation (AWI) are conducting research into the development of new and emerging technologies which will enhance producers' abilities to address these challenges (Sheepmeat Council of Australia, 2017; AWI, 2017; Sheep CRC, 2017).

The Sheep CRC believes apps and online tools will be the most cost-effective method of delivering new knowledge and best practice management tools to the industry (Sheep CRC, 2016). A significant challenge to the Australian sheep industry has been identified as the continuation of technological transformation through the use of cutting edge research to enhance sheep wellbeing, introduce value-based trading of sheepmeat and deliver affordable technologies for DNA-based genetic improvement. The Sheep CRC aims to continue the technological transformation of the sheep industry through three primary programs (Sheep CRC, 2017a):

1. Enhanced sheep wellbeing and productivity program – sheep wellbeing risk predictions developed based on Big Data applications that draw on weather data, analysis of the Information Nucleus database and regular monitoring to identify management factors that influence risk to wellbeing and productivity. This analysis will be used to build web-based apps that use past and current data to inform management decisions involving culling, nutrition and animal health treatment.
2. Quality-based sheepmeat value chains program – Improved efficiency of the sheepmeat value chain will be achieved through application of new knowledge and technologies that provide accurate prediction of eating quality and saleable yield of retail cuts most suitable for consumers and retailers. The same research solutions developed for lamb supply chains will be used to create opportunities for currently undervalued heavier lean lamb and yearling Merino carcases.
3. Faster affordable genetic gain program – The development of more accurate and affordable DNA tests will bring genomic technology into the mainstream of Australian sheep breeding practices. Next-generation DNA sequencing of samples in the Information Nucleus bio-bank will be used to both boost the accuracy of genomic selection tools and develop significantly cheaper DNA tests for ram breeding programs. Faster rates of genetic improvement and more flexible breeding objectives set the scene for future growth and increased productivity.

Developed by the Sheep CRC in collaboration with Telstra, NSW Department of Primary Industries and Pivotal Labs, RamSelect Plus, an enhanced version of its popular web-based genetic selection app, was released in 2015. The tool aids in selection of genetics which match the breeder's purpose – whether that be wool production, meat eating quality or a range of other factors which impact the profitability of a flock (Sheep CRC, 2016). RamSelect Plus also features innovative benchmarking and monitoring tools, such as the Ram Team Manager and Flock Profiler, which allow farmers to ensure their rams are carrying the right combination of genes to support the business's key profit drivers.

Wool

In 2015, Australian Wool Innovation (AWI) set up DigiBale, a commercially focused company responsible for developing and distributing digital tools for Australian woolgrowers and other supply chain participants. Some of the products developed to date include a lambing planner, shearing app and Bluetooth humidity monitor. Current RD&E investment focus of AWI involves the development of low-cost, smart sheep ear tags capable of generating maternal pedigree, geo-location, and other behavioural information of commercial value (e.g. pest notifications); virtual fencing (grazing management and stock movement); and development of platforms to enable automated pasture production assessment and its integration into farm apps.

AWI are also involved in a number of training and education initiatives associated with technology uptake in the areas of sheep and wool management, and wool harvesting and preparation, targeting industry engagement.

The AWI 2016-19 National RD&E strategic plan outlined the *Farm Automation Innovation* program which will seek to ensure Australian woolgrowers are provided practical, low-cost digital tools which automate routine operations, support productivity and welfare improvements, and genetic progress.

Pork

Australian Pork Limited (APL) is the industry service body for Australian pig producers. The APL *Strategic Plan: 2015–2020* identified key demand change drivers, which included the combination of technology and increasing public interest in food causing consumer groups to fragment into an increasing number of smaller segments. This will make provenance, production systems and product ranges more important and increasingly diverse.

Both APL and the Pork CRC have indicated industry-wide commitment to the focus on technology adaptation and adoption in the primary areas of:

- Emissions reduction
- Waste management – PigBal is a tool for providing realistic estimates of solids and major nutrients in piggery waste streams.
- Water use,
- Renewable energy,
- Environmental sustainability
- Animal welfare and heard health management – Technologies for optimal reproduction, nutrition and health of sows housed in groups during lactation; diagnostic tools for pests and disease; and data collection protocols.

Current projects and research outcomes are associated with:

- AusScan Online – A new online platform, aiming to revolutionise feed ingredient near infrared reflectance spectroscopy (NIRS) calibrations (licensing agreement between Pork CRC and Aunir).
- PigPass – A system administered by APL on behalf of the pork industry. A PigPass National Vendor Declaration (PigPass NVD) functions as a movement document for livestock traceability and provides a declaration that pig production has been carried out in a way that meets agreed industry and government standards relating to food safety, animal disease control and animal welfare. Buyers and processors rely on this information to ensure only the safest food enters the supply chain (APL, 2017).

Dairy

Digital technology has been successful in supporting farmers in an increasingly open and highly competitive market. Big Data will take farm productivity to a new level (Dairy Australia, 2015). The industry has experienced improvements in animal management through the use of monitoring systems (pedometers, temperature recording devices) and sensors (milk meters, yield recording devices). Dairy Australia led the first mid-infrared (MIR) technology trial through the Australia Government Rural R&D for profit program. MIR technology provides important genomic information from milk samples for improved cow selection for production, feed efficiency and health (Dairy Australia, 2016). The farmer is able to predict which cows will be most profitable at lactation (RIRDC, 2015).

Eggs

Poultry Hub (2017) outlined a recent project by the Poultry CRC, which involved a proof-of-concept 'computer vision' where a robotic system capable of scanning the egg collection belt was developed to identify potential blockages. The robot's software could differentiate between eggs and non-egg objects with 95% accuracy. A second component of the Poultry CRC proof-of-concept project investigated whether computer vision could also be used to count hens in cages. This was the first step in a process to develop a robotic method for monitoring the health and welfare of hens. The capability of remote sensing technology for measuring biological parameters indicative of production efficiency is improving. Such data can be streamed to computerised control systems which assess the information and instruct the delivery of precise nutrient requirements, or the manipulation of environmental conditions, etc., for optimal performance of birds. Through integration of the production and health and welfare measures, farm managers would be able to continuously monitor and micro-manage their birds for optimal health, welfare and performance. The long-term objective of the proof-of-concept project is to identify work tasks that are repetitive, time consuming and able to be automated and monitored by computers.

An example of a robotic process in the modern cage egg industry is the use of integrated conveyor belts to collect and transport eggs to the packing room. Conveyor belts eliminate the need to handle eggs, which is especially relevant in modern sheds with tiered cages. Egg collection via conveyor belts also reduces occupational health and safety (OH&S) risks associated with manual egg collection at heights and under low levels of illumination.

While robotics is common place in most poultry production enterprises, advances and new applications present some of the greatest opportunities for innovation in Australian poultry industries. However, current challenges include: the capacity and capability for technologies to be extended to monitor the health and welfare of the birds, the identification and tracking specific birds – especially under low light levels and the issues of lack of contrast between subject and background, and computer capability and data processing.

Chicken meat

The Australian chicken meat industry has a history of rapid adoption of new technology. Most commercial meat chicken farms are intensive, highly mechanised operations that occupy relatively small area compared with other forms of farming. Opportunities for continued productivity enhancements, through the adoption of improved technology on-farm (in areas such as bird health and welfare, husbandry, nutrition and feed management) and elsewhere are key components of the RIRDC chicken meat program. Robotics and automated systems are among the most common technologies utilised in Australian poultry production. Amongst other tasks, robots are capable of automating the feeding process and managing shed ventilation. In the chicken meat processing sector, robots perform tasks such as automatic transfer of carcasses and detection of defective carcasses. The utilisation of robots is expected to increase in the future as other capabilities are developed that improve the ability to remotely monitor birds.

Wine

The Australian wine industry is currently making significant investments in projects targeting advances in the development of digital technologies and improvements to productivity of vineyards, including improvements to accuracy and timeliness of yield predictions through the use of spectroscopy.

Commencing in 2016, the four-year, $3 Million Rural R&D for profit project, *'Digital technologies for dynamic management of disease, stress and yield',* is a collaboration between 15 organisations, including Wine Australia, CRDC and HIAL, and research partners at the CSIRO, University of Queensland, University of Tasmania, The Fraunhofer Institute (Germany), University of South Australia and the Australian Wine Research Institute (AWRI). Undertaken across multiple Australian wine regions, the project is targeting the integration of systems capable of simultaneous measurement and data provision to assist cross-sectoral holistic decision-making for the management of disease, stress and yield.

In 2016, Wine Australia piloted VinSites, a consolidated national data set for the wine sector that provides critical data to track Australian wine from the vineyard through to consumption. VinSites is designed to improve the quality, accessibility and value of the vast amounts of data that are often locked away in many disparate repositories and tools used throughout the Australian grape and wine community. Importantly, VinSites aims to collect critical data and provide Australia's grape growers and wine producers with access to accurate and timely data to support their businesses free of charge (Wine Australia, 2017).

SkySquirrel Technologies Inc. is a crop-analytics company that develops drone-based technology for monitoring crop health, with a primary focus on improving crop yields and reducing costs at commercial vineyards.

Forest and wood products

As a relatively small player in the global forestry industry, Australia's forest and wood product industry has been well engaged and is poised for digital change. Forest and Wood Products Australia (FWPA) are participating in the uptake of digital technologies and the strengthening of data availability through their *2014–2019 Strategic Plan* (FWPA, 2014). Outcomes from the plan include improved coordination and building better systems for data collection and analysis, the development of a secure online portal for consolidation and access to key data series and improved working relations with ABARES and other statistical collection and analysis agencies.

The ARC Centre for Forest Value at the University of Tasmania is currently undertaking a range of research projects that span the forest products supply chain. Part of the project will investigate supply chain integration and management. The research outcomes include the use of smart information and sensor technology to maximise useful information flows across the forest product value chain. It also includes the development of software applications and tools at key points in the supply chain to improve information and data transfer.

A number of transformative technologies are having a significant impact across the forestry value chain (EY, 2016). Biotechnology applications have played a role in improving wood quality, pest management and have supported improved growth rates of trees, improved quality practices. Types of biotechnology applications include:

- Genomics.
- Marker aid selection and breeding.
- Genetic Engineering.

Current Royal Melbourne Institute of Technology (RMIT) research has worked to develop an open source software package to advance forest management, focusing on the way forest data is captured using sensor technology for forest categorisation. The understanding of data and information relating to forest structure and tree height is central to inform climate change policy, sustainable forest and bushfire management. It can be put into practice by government to support international reporting and monitoring obligations for forests. The joint research project is funded by the CRC for Spatial Information, the Victorian State Government and RMIT (Geospacial Science).

The Tasmanian Government Department of Primary Industries, Parks, Water and Environment (DPIPWE) offer a comprehensive digital vegetation map of Tasmania. TASVEG and TASVEG Live provides a description of 156 identified vegetation types. It is a vital tool for land use planning and sustainable forestry management. TASVEG Live was delivered in 2014, enabling a more up-to-date picture of the state of native vegetation.

The Flinders Centre for Nanoscale Science and Technology (CNST) have partnered with Australian nanotechnology company 3RT Holdings Pty Ltd to develop methods for converting cheap pulpwood into a highly sustainable hardwood alternative with enhanced properties, known as 3Wood. The 3Wood hardwood substitute has features that include being termite resistant, fire retardant with improvements in UV lighting and water resistance currently in the development stages.

Livestock exports

Current technology being adopted in the livestock export sector is largely driven by concerns around animal health and welfare. In response to this, there have been developments in high tech electronic ear tags to track and trace cattle from ‘conception to consumption’, storing data on animal health. The technology has been introduced to monitor Australian livestock in overseas feedlots. The system was developed by Global Compliance, a Jakarta-based company in line with the Exporter Supply Chain Assurance System (ESCAS) and serves to ensure that exporters can trace stock throughout the supply chain and minimise any leakage of animals outside of ESCAS-accredited facilities. It is currently being expanded into Australia to enable the monitoring of cattle across the entire supply chain. The first facility to adopt the technology is an export holding depot near Darwin. The extension aims to guarantee traceability of the animal through loading, unloading and processing right up until slaughter (Nason, 2014).

Fisheries and aquaculture

The Australian Fisheries Management Authority (AFMA) and the Fisheries Research and Development Corporation (FRDC) are leading the drive towards a more digitalised fisheries and aquaculture industry. Most jurisdictions are following the lead of AFMA in implementing vessel monitoring systems and e-logging. However, as fisheries operations across many jurisdictions collect more data, the segregated manner in which it is being collected is reducing its usefulness. Initiatives such as the Integrated Marine Observing System (IMOS), Australian Oceans Data Network (AODN) and Commonwealth/Queensland reporting on data.gov reinforce that the whilst some of the data is available, linkages at the current time are limited.

Two broad strategies include improved quality of data and the support for data transfer between research and compliance agencies and are largely focused around demonstrating the sustainable use of a public resource. The AFMA's 2015–2018 Corporate Plan includes support for the implementation of technologies such as electronic monitoring and logbooks to improve the quality and accessibility to crucial fisheries data and improve information flows (AFMA, 2015). The AFMA undertook the rollout of a mandatory e-monitoring system in 2015 as a reliable and more cost- effective way to verify logbook data. The system involves a set of cameras and sensors on board fishing vessels that transmit live location data to AFMA for real-time monitoring as opposed to human observers. It has proven to be a powerful tool for the capture of data with benefits of increasing the accuracy of catch reporting and verifying interactions with threatened species in sensitive fishing zones.

The FRDC is also looking at opportunities to use data to demonstrate sustainable fishing and growth. FRDC is currently looking to foster a more constructive fisheries and aquaculture data environment through the Fisheries digital data framework workshop. The aim of the workshop is to evolve requirements for fisheries and aquaculture data and gain an understanding of the requirements and concerns about data capture, sharing and governance from key industry stakeholders including fisheries managers, scientists, researchers and business. This will support the development of more available and useful fisheries and aquaculture data with benefits for both industry and commercial bodies (FRDC, 2017).

The Likely Development of Digital Agriculture in Australian Agriculture

The challenges and opportunities associated with digital agriculture vary by sector. The likely development and uptake of digital agriculture products and services is influenced by a range of factors. However, there are three key dimensions that determine the overall potential for new business models to emerge:

- **Market size** – the size of the opportunity for potential digital agriculture users (economic benefits) and attractiveness of the sector to product/ service providers.
- **International Spillover** – the level of international activity to develop digital agriculture technologies in this industry, and the suitability of these technologies to Australian conditions/ the Australian market.
- **Digital maturity** – the current level of digital agriculture use, and the capability and willingness of users to adopt digital agriculture products and services.

Market size

The potential market for digital agriculture products and services is related to the size of the industry and the structure of the value chain. Results from the economic modelling were used to consider the potential market size for each industry.

Industry size is typically correlated to technology market size. In other words, it would be expected that there is greater overall demand for digital technologies in larger industries, and consequently greater opportunities for technology developers seeking to market their product or service. Similarly, the size of individual businesses is a significant factor in the adoption of technology. Industries such as cotton, where the typical producer runs a large and capital-intensive business, could be in a better position to fund the purchase of new technology than in the sheepmeat industry, where the average producer runs a substantially smaller operation.

Factors considered during the analysis include:

- Main products
- Farm business size
- Differences between small and large producers
- Employment
- How much is produced?
- What is the value of production?
- Domestic value and consumption
- Export value and volume

At the same time, the structure of the value chain can influence how new technologies are adopted. For instance, sectors with a high degree of vertical consolidation are characterised by greater coordination of activities between production and retail. They could be expected to have higher levels of technological uptake given smaller barriers for implementing new technologies. Many of the drivers of digital agriculture that are likely to influence the production sector are coming from further up the value chain. The market power of large retailers and processors can act as a 'pull' or 'push' factor for technology.

Value chain factors influencing decision agriculture adoption include:

- Size of processors – turnover, market share/power
- Ownership – Australian or foreign owned?
- Barriers to new entrants in the processing sector
- Extent of vertical integration and concentration of processing.
- Factors affecting pricing at the processing/ wholesale level
- Factors affecting pricing at the retail level
- Quality assurance systems – are they processor driven?

International Spillover

Digital agriculture is a global phenomenon. Technological advances that are relevant to Australian agriculture are occurring rapidly in a number of regions, including the US, Europe and East-Asia. Input from US-based AgTech consultancy firm, Prassack Advisors, provided insight into the potential international spill-over of technology by sector. *Appendix 4* contains descriptions of digital agriculture products and services available internationally.

The list is by no means exhaustive but rather is designed to provide an overview of the range and scope of developments across the sectors that are reported on here as well as some other general categories such as sensors and tractor control. While the technology described in every case study has the potential to be used in Australia, some are more immediately applicable than others. Each case study has been colour coded green (immediately applicable) or yellow (requires further work). *Table 4.3* provides a summary of the products in *Appendix 4* and their susceptibility for international spillover.

Products have been yellow coded if they require integration with specific data sets that may not be readily available in Australia (e.g. soils information), are specific to regulatory compliance for another country, or require a very high level of connectivity infrastructure.

Green coded products do not have an obvious technology or data limitation to being used in Australia, however there still may factors which limit their attractiveness in the Australian market such as market size or lack of partnership opportunity.

In general, there is expected to be a greater level of activity in globally significant sectors. For example, the grains industry is a major global industry whereas the wool and sheepmeat industries are relatively small by comparison. While this is certainly born out in terms of where global investment in AgTech is targeted, there are other factors which determine the level of applicability of products to the Australian market.

Table 4.3 Potential Spillover of International Technology

	CASE STUDY 1	CASE STUDY 2	CASE STUDY 3	CASE STUDY 4	CASE STUDY 5	CASE STUDY 6	CASE STUDY 7
RICE	SUSTAINABILITY DATA						
GRAINS	SEED SELECTION TOOL	MACHINE + AGRONOMY DATA	FARMER DATA COOPERATIVE	FIELD RECORD KEEPING	MONETISE MACHINE DATA	MONETISE WITH WHOLESALERS	
COTTON	NOZZLE BY NOZZLE CONTROL	SOIL MICROBES + PLANT GENETICS	TRACE FROM FIELD TO GARMENT	TRACKER			
SUGAR	PRODUCTIVITY & DELAY MGMT						
HORTICULTURE	SOIL TESTS	SENSOR NETWORKS	MACHINE DATA	LABOUR PAYROLL			
CATTLE AND SHEEP	PASTURE MANAGEMENT	FLOCK MANAGEMENT	WATER MANAGEMENT				
WOOL							
PORK	SOW SENSORS	BARN MANAGEMENT	NITROGEN TRACKING				
DAIRY	CALVING SENSORS	COW HEAT SENSORS	COW HEALTH SENSORS	FACIAL RECOGNITION	GENOMIC ANALYSIS	GENOMIC TESTING	FIND MY FARMER - TRACE
EGGS	LAYER HEALTH SENSOR	PRINTING - TRACEABILITY					
CHICKEN MEAT	POULTRY OPERATION MGMT				**BEES**	BEE HIVE SENSORS	
WINE	VARIABLE RATE DRIP IRRIGATION	LIDAR 3D VINEYARD MAPPING					
FORESTRY	FOREST INVENTORY	PHODAR FOREST MONITOR					
LIVESTOCK EXPORTS							
MEAT PROCESSING							
FISHERIES, AQUACULTURE	NET CAMERAS	FEEDERS	FEEDERS	BLOCK CHAIN & PROVENANCE			
IMAGERY	CROP FORECASTING						
SENSORS	POTATO SENSORS+SW	IOT SENSOR NETWORKS					
TRACTOR CONTROL	AUTONOMOUS CONTROL	LOW COST MOBILE APP GPS	OPTIMAL FIELD PATH				

Green – Immediately applicable
Yellow – Requires further work/ integration
Red – Limited spillover/ No cases studied identified

An important factor in international spillover of technology is the level of similarity in production systems (including genetics, environment, and management practices) between Australia and the country of origin of the product or service. This affects the suitability and transferability of products to meet user needs. For example, Australia's intensive livestock industries (e.g. pork, eggs, chicken meat and dairy) are much more similar to those in Europe or North America than is the case for the extensive livestock industries (e.g. beef, sheepmeat, wool). This means it is more likely that 'off the shelf' products or 'plug and play' business models from Europe or North America could be applied in the intensive livestock industries.

Extensive livestock industries and the cropping sector have unique agronomy and environmental challenges and often require integration with datasets specific to the Australian landscape and production context. Corresponding with these differences, the rice, grains, cattle and sheep, and forestry sectors were perceived to have less immediately applicable digital agriculture products and services than other sectors.

Case studies for the wool, livestock exports and red meat processing sectors were not presented due to the lack of international activity in the wool and live export sectors and the more proprietary and bespoke nature of the red meat processing sector.

Sectoral spillover also provides possibilities for technology expansion. For example, many of the case studies listed in the dairy sector in this analysis are general animal monitoring technologies that could be utilised in other intensive livestock industries. Blockchain technology for provenance demonstration and programs which monetise farmer collected data have applicability across multiple sectors.

Digital maturity

Digital maturity refers to the fact that digital technologies and their users evolve over time. A high level of digital maturity is characterised by capable users who have the skillsets, attitude and readiness to use technology extensively to support their decision-making. This includes being able to quickly assess the costs and benefits of a new technology, and having trust in data management processes.

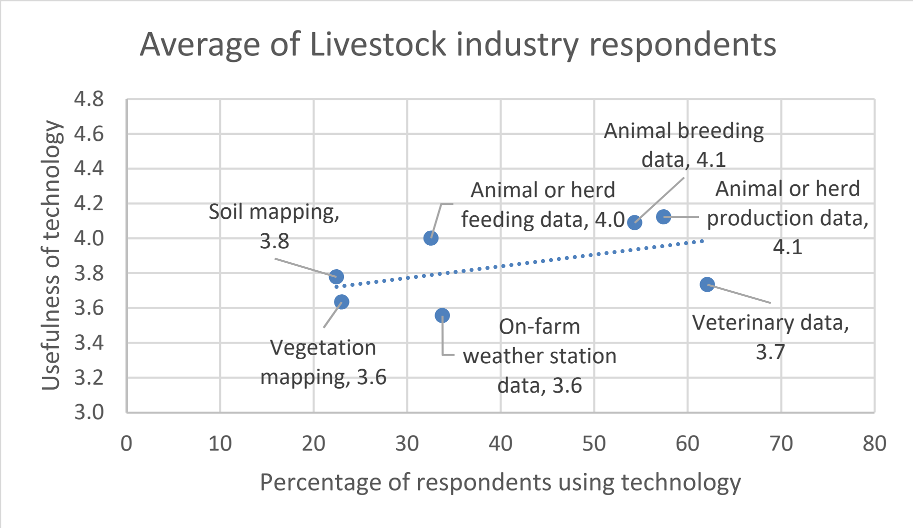
Results of CSIRO's producer survey and the analysis of current literature suggest there are six key elements of digital maturity as it relates to decision agriculture:

- Level of current use
- Digital capabilities of users
- Perceived value/ satisfaction with current digital use
- Availability of relevant decision-support tools
    - Current level of investment by sector RDC in decision agriculture
    - Decision support tools available
    - Key sector decision support needs
    - Private sector R&D
    - Relevance of international science
- Availability of relevant data
    - Current public and RDC data – types of data sets

    - Farm data collection – technologies and adoption
    - Farm performance benchmarking
    - Key production inputs (and data outputs)
    - Diversity of production systems – intensive vs extensive
- Extent of existing commercial platforms and digital agriculture services
    - Current commercial platforms and digital agriculture services
    - Demographics – number of farmers, age, education, business size
    - Adoption of precision agriculture
    - Education, training and skill requirements

Interestingly, advanced levels of digital maturity do not necessarily equate with higher levels of value being delivered. An analysis of data from the CSIRO producer survey comparing the livestock sector with the cropping sector reveals that the most adopted technologies are not necessarily the ones delivering the greatest value.

Figure 4.5 illustrates adoption rates and attitudes towards a range of decision agriculture technologies that were surveyed. It shows a slight trend in the cropping industry of less value being derived from more adopted technologies. The cropping industries have been using precision agriculture for many years and many technologies that enable decision agriculture are now embedded in machinery and are used as part of normal farming operations. The value proposition derived from the data that is collected from these technologies remains poorly defined however, so while there is a large use of technology the perceived usefulness is low.



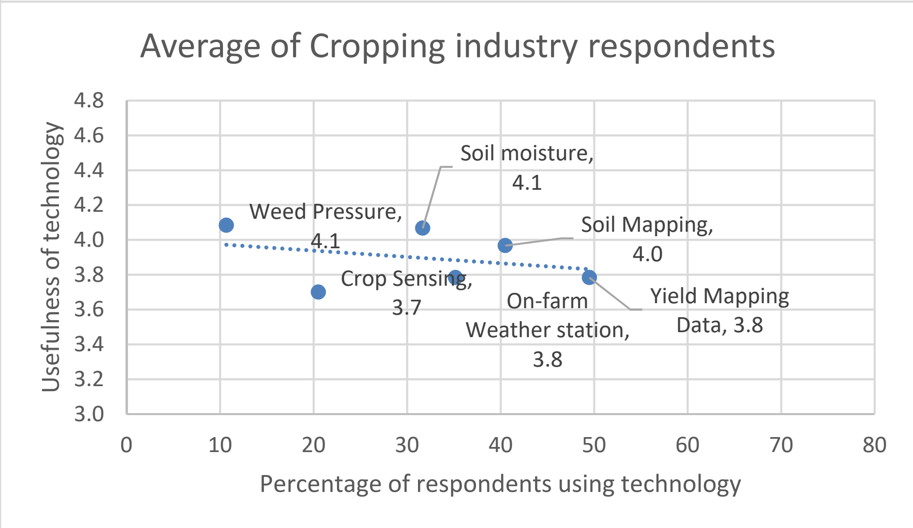


Figure 4.5 Prevalence versus usefulness of technology. (Source: Zhang et al. 2017)

An Assessment of the Business Environment for Decision Agriculture by Sector

The size of the opportunity for decision agriculture varies by sector and is shaped by several factors including the market size, potential international technological spillover, and the digital maturity of the sector (*Table 4.4)*. Together these factors suggest the potential economic impact of decision agriculture, the specific challenges facing the sector, and readiness of producers to adopt new technology.

The red meat processing sector stands out as a sector with likely very high levels of decision agriculture development. This is influenced by the large size of players in the sector, the high level of digital maturity, and the high potential for international technological spillover (e.g. advanced manufacturing systems from North America and Europe).

In the extensive livestock sectors, it is likely that there will be a greater level of activity to develop decision agriculture for the beef sector than in the sheepmeat sector. This largely reflects the larger size of the beef sector (and size of the market), and greater potential for international technological spillover.

Australia is the dominant player in the global wool industry and it should be expected that many decision agriculture developments will occur within Australia. The industry's synergies with the sheepmeat sector (given the increasingly dual-purpose nature of most sheep enterprises) could help attract investments in technology development relevant to sheep production.

In general, there is potentially greater opportunity for international technology spillover in the intensive industries than the extensive industries. This reflects the relative homogeneity of intensive livestock production systems and the large global market for pork, dairy and poultry.

Based on market size, international spillover, and digital maturity it appears that the overall opportunities for some aspects of decision agriculture in the plant/ cropping industries are generally higher than for the livestock industries. There is a high potential for technology spillover in most cropping industries due to the global significance of these industries and some similarities in management practices (e.g. the use of imagery data to support biomass management) and machinery use (e.g. automated weed control). Furthermore, cropping industries generally show a high level of digital maturity reflecting aspects such as the relatively long history of precision agriculture (e.g. GPS-guided machinery).

Table 4.4 A summary of factors affecting the likely emergence of decision agriculture business models by sector

Sector	Sheepmeat	Wool
Market size	Medium – Large	Medium – Large
	Baseline GVP (14–15): $2,998m Potential GVP (unconstrained): $3,514m • Moderate sized market for new technologies (innovation likely to be driven by Australian initiatives). • Potential high degree of synergies (and technological spillover) with the wool sector.	Baseline GVP (14–15): $2,550m Potential GVP (unconstrained): $3,002m • Moderate sized market for new technologies (innovation likely to be driven by Australian initiatives). • Potential high degree of synergies (and technological spillover) with the sheepmeat sector.
International Spillover	Low	Low
	• Australia is one of a few major exporting nations. • Very limited potential for international spillover. • Spillover from processor-led initiatives are more likely to drive adoption of new technologies (e.g. objective carcase measurement).	• Australia is the dominant global supplier of raw wool. Minimal domestic value-adding (e.g. processing) occurs domestically. • Very limited potential for international spillover. • Global consumer/ retail trends may influence on-farm practices (e.g. adoption of technology).
Digital Maturity	Low – Medium	Low
	• Relatively low level of on-farm data collection. • Strong interest from producers in the potential of objective carcase measurement to provide valuable on-farm decision-support (e.g. identifying superior genetics for meat eating quality). • Utilisation of digital agriculture highly constrained by connectivity.	• Low level of on-farm data collection. • Utilisation of digital agriculture highly constrained by connectivity.

Sector	Beef	Red Meat Processing	Livestock Exports
Market size	Very Large	Very Large	Medium
	Baseline GVP (14–15): $10,461m Potential GVP (unconstrained): $12,149m • Large industry size and market for new technologies. • Australia is a major global player in beef trade. • Vast differences between the scale and systems of northern and southern beef sectors.	Baseline GVP (14–15): $14,553m Potential GVP (unconstrained): $16,614m • Large market for new technologies (likely to attract new business models and products/ services).	Baseline GVP (14–15): $1,601m Potential GVP (unconstrained): $1,673m • Australia is largest and most technologically advanced player in the global market.
International Spillover	Low – Medium	High	Low
	• Limited international spillover for on-farm technologies given Australia's unique climate and production systems. • Higher potential in intensive livestock finishing environments such as feedlots. • Technologies more likely to spillover from processing sector (e.g. objective carcase measurement).	• Australia's need to remain internationally competitive will drive cost-reducing initiatives (e.g. automation and robotics) and product quality/ marketing initiatives (e.g. provenance and eating quality assurance).	• Limited potential for international technology spillover. • Technology spillover likely to occur from associated industries (e.g. animal health and monitoring technologies from the beef feedlot sector, and supply chain management technologies from the transport industry).
Digital Maturity	Low- Medium	High	Medium – High
	• Utilisation of digital agriculture highly constrained by connectivity. • Significant trust issues about data ownership and sharing between production and processing sectors. • High level of data collection in some sectors (e.g. seedstock and feedlots).	• High level of digital maturity in industry (e.g. digitised record keeping, carcase/ product tracking). • Limited connectivity constraints. Largest constraint likely to be data analytics/ decision support tools.	• Generally high level of digital maturity, driven in part by the need to meet regulatory requirements. • Use of digital technology constrained at some points in the supply chain (e.g. overseas lairage).

Sector	Eggs	Chicken Meat
Market size	Medium	Medium
	Baseline GVP (14–15): $729m Potential GVP (unconstrained): $809m • Relatively small and domestically focused industry. • Highly integrated value chain (on-farm technological change likely to be driven by the processing and retails sectors). • The several large integrated businesses (input supplying, production, egg collection and wholesaling) are best placed to benefit from decision agriculture.	Baseline GVP (14–15): $2,084m Potential GVP (unconstrained): $2,587m • Relatively small and domestically focused industry. • Highly integrated value chain (on-farm technological change likely to be driven by the processing and retails sectors). • The several large integrated businesses (input supplying, production, egg collection and wholesaling) are best placed to benefit from decision agriculture.
International Spillover	High	High
	• High potential for international spillover of technology given high degree of homogeneity between Australian and international production systems.	• High potential for international spillover of technology given high degree of homogeneity between Australian and international production systems.
Digital Maturity	Medium – High	High
	• Digital maturity varies by production system (e.g. caged and barn-laid systems are generally more digitally advanced than free-range systems). There is already a high-level of automation and robotics in the sector.	• Digital maturity is generally high but varies by production system (e.g. barn systems are generally more digitally advanced than free-range systems). There is already a high-level of automation and robotics in the sector.

Sector	Pork	Dairy	Fisheries and Aquaculture
Market size	Medium	Large	Medium
	Baseline GVP (14–15): $1,084m Potential GVP (unconstrained): $1,139m • Moderately sized, domestically-focused industry. • Highly integrated value chain (on-farm technological change likely to be driven by the processing and retails sectors).	Baseline GVP (14–15): $3,343m Potential GVP (unconstrained): $3,840m • Large market for new technologies (likely to attract new business models/ products from overseas). • Globally significant industry.	Baseline GVP (14–15): $2,132m Potential GVP (unconstrained): $3,026m • Moderately sized industry (domestic and export focused segments). • Growing level of imports.
International Spillover	Medium – High	Medium	Medium
	• High potential for direct international technology spillover given high degree of homogeneity between Australian and international production systems.	• Likely direct technological spillover from New Zealand and Ireland (similar pasture-based systems). • Technologies from some regions may need to be adjusted to suit Australian systems (e.g. hot summers and predominately pasture-based systems c.f. total mixed ration systems in northern Europe).	• Moderate potential for technological spillover in wild-caught fisheries sector and high potential in aquaculture.
Digital Maturity	Medium	Medium	Medium
	• Digital maturity is generally high but varies by production system (e.g. housed systems are generally more digitally advanced than free-range systems).	• Utilisation of digital agriculture highly constrained by connectivity. • Strong culture of benchmarking farm business performance and adoption of new technology.	• Digital maturity varies significantly between sectors/ target species (e.g. generally highly advanced in aquaculture and low-to-medium in wild-caught fisheries).

Sector	Rice	Grains	Cotton
Market size	Small	Very Large	Medium – Large
	Baseline GVP (14–15): $260m Potential GVP (unconstrained): $338m • Relatively small industry size and market for new technologies. • Major role for processing sector (SunRice) to support the development and trial of new on-farm technologies.	Baseline GVP (14–15): $11,522 Potential GVP (unconstrained): $17,452m • Very large market for new technologies (likely to attract new business models). • Australia is a large player in this very large global industry.	Baseline GVP (14–15): $1,413m Potential GVP (unconstrained): $1,807m • Moderately sized industry. Australia is the world's 4th largest exporter (& 7th largest producer in total). • Australian sector is regarded as global leader in digital agriculture.
International Spillover	Medium	High	High
	• Limited potential for rice crop specific technologies. • Likely technology spillover from other cropping industries (e.g. horticulture and cotton for water management technologies, and grains/ oilseeds for data analytics/ decision support tools).	• Likely direct spillover of products and services (and business models) from North America, including off-the-shelf/ 'Plug-and-Play' technologies. • Need for international technologies to be tested and adjusted to suit Australian conditions (e.g. different climate & agronomic factors) and Australian constraints (e.g. low internet connectivity).	• Likely international spillover from other broadacre cropping industries. Many cotton specific innovations are likely to be developed within Australia. • Likely technology pull-through from large global retail market (e.g. fashion industry and consumer goods).
Digital Maturity	Medium	High	Very High
	• Increasing adoption of digital water management technologies. • Utilisation of digital agriculture highly constrained by connectivity.	• High historical adoption of precision agriculture sets precedent for decision agriculture. • Adoption constrained by poor connectivity and limited capability in data analytics (& lack of decision support tools). • Utilisation of digital agriculture highly constrained by connectivity.	• High historical adoption of precision agriculture sets precedent for decision agriculture. • Highly capable and digitally mature user base (generally large, capital-intensive businesses with high existing adoption of precision agriculture).

Sector	Sugar	Horticulture
Market size	Medium – Large	Small
	Baseline GVP (14–15): $1,257m Potential GVP (unconstrained): $1,548m • Moderate sized market for new technologies (innovation likely to be driven by Australian initiatives, including response to regulatory requirements).	Baseline GVP (14–15): $1,018m Potential GVP (unconstrained): $1,421m • Moderately sized industry. New business models likely to emerge addressing high labour costs and quality assurance requirements.
International Spillover	Medium	High
	• Global consumer trends and market requirements (e.g. Bonsucro initiative) likely to influence technology adoption and use of data on-farm/ across the supply chain. • High potential for spillover from technologies other broadacre sectors (e.g. VRT from grains/oilseeds sector).	• High potential for direct international spillover of technologies, particularly for crop management and monitoring (e.g. automation, robotics, sensors). • High degree of integration across the value chain. On-farm technological change likely to be driven by the processing and retails sectors.
Digital Maturity	Low – Medium	Medium – High
	• Relatively low historical adoption of precision agriculture technologies than other cropping industries. • Long timeframes between plantings (i.e. ratooning after harvest) will limit the frequency of some decision agriculture practices (e.g. row-spacing and irrigation layout in light of given soil and nutrient data).	• Uptake of digital technology is occurring rapidly, but varies by business size (e.g. large corporate vertically integrated company vs small family business). • Australia is leading the world in the development of some in-field sensors and robotics for the horticulture sector.

Sector	Forest and Wood Products	Wine
Market size	Medium	Large
	Baseline GVP (14–15): $14,864m Potential GVP (unconstrained): $20,375m • Large industry with relatively few players (and increasing consolidation). • High potential for technology development in the timber processing sector (driven by need to reduce labour costs and wastage of wood).	Baseline GVP (14–15): $5,865m Potential GVP (unconstrained): $6,571m • Australia is a major player in the global market. The value proposition for new technologies is different to most sectors. The focus is on optimising quality and not quantity (i.e. Meeting quality specifications rather than chasing yield gaps).
International Spillover	Medium	High
	• Potential spillover of technology from New Zealand, North America, and Scandinavia (including remote monitoring and market/ regulatory compliance tools).	• Technological spillover from other sectors is likely (e.g. remote sensing and UAVs from horticulture sectors). • Highly integrated value chain (on-farm technological change likely to be driven by the winemaking sector).
Digital Maturity	Medium – High	Medium – High
	• Adoption of decision agriculture tools for forest (and plantation) management limited by long-term production system (e.g. 25-year cycles).	• Digital maturity varies between small contract growers and large, vertically integrated operations.

The Impact of Current Constraints on Decision Agriculture

This report has identified major opportunities for decision agriculture to improve the productivity and profitability of Australia's agricultural industries. However, it is unlikely that the full economic potential of decision agriculture will be realised until several existing interconnected constraints are addressed. These constraints affect both the adoption of existing decision agriculture technologies and practices, as well as the likely emergence of new business models (and their associated products and services). In other words, to enable on-farm innovation and innovative business models it is critical that these constraints are addressed. This section discusses the impacts of the following major constraints on the current and future development of decision agriculture:

- **Availability of appropriate data**
- **Data analytics and decision-support tools**
- **Connectivity**
- **Trust & legal barriers**
- **Value proposition (e.g. profit drivers)**

Availability of Appropriate Data

Darnell and Barry (2017) and Skinner (2017) have explored in depth the issues around data availability, analytical capacity and reference architectures as part of the P2D project. This section references their work with specific regard to the economic benefit and business models of decision agriculture.

The availability and accessibility of appropriate data has a significant impact on the potential for new digital agriculture businesses to emerge. As the power of computational technologies have increased, and the costs of data storage has decreased, there has been a massive expansion in the volume of data collected on-farm and across the value chain. However, there are issues associated with handling these volumes of data, as well as issues with the variety of data (e.g. multiple data formats) and veracity of data (quality, accuracy, and completeness of data sets).

For data analytics to inform decision-making processes the underlying data must be available. For example, some assessments of crop performance and varietal selection based on soil properties requires the availability of detailed data on the spatial distribution of soil types that can be compared with yield maps from the appropriate crop.

There has been a rise in private sector collection of weather data, driven by new technologies and business models, with the volume of on-farm data collected, and stored using the cloud, rising exponentially in recent years. However, the availability of appropriate data has been constrained by poor connectivity. Slow data upload speeds in rural areas limiting the velocity of agricultural data is constraining the capacity for producers to utilise cloud-based data storage systems. Many producers are still reliant on paper-based data storage systems.

There is an increasing need for investment in foundational public-sector datasets, particularly those pertaining to soils, water and climate/weather, that provide a reference point critical to the validation of privately collected data. Additional issues that require attention include those concerning data accessibility. A consensus position from the industry workshop conducted as part of this project, was that historical datasets from Rural Research and Development Corporations (RDCs) and other public research was very difficult to access. This suggests that many datasets are currently underutilised.

The willingness to share data was also a prominent concern among industry stakeholders, however there is big difference between sectors. For example, in some sectors, such as dairy, benchmarking is common practice, while in others, such as wool, there is a greater reluctance to share benchmarking data (e.g. animal genetics).

While some decision agriculture applications do not rely on multiple data sources, the most disruptive and potentially highest impact in terms of productivity change do require multiple data sources for analysis. For example, in the beef sector 85% of the estimated total productivity gain is derived from management changes informed by linking genomics, carcase and production data. In the grains sector 78% of the estimated productivity gain is from decision agriculture applications that require multiple data sources (*Table 5.1)*.

Summary

To facilitate the development of new business models there needs to be major initiatives to improve several data related issues, including:

- strengthening foundational public data sets (e.g. soil, water, climate);
- improving coordination and sharing of cross-sectoral (i.e. multiple RDC) data sets;
- resolving issues associated with different data governance approaches (e.g. inconsistent data systems architectures and ontologies); and,
- investing in improving connectivity infrastructure to improve the functionality and storage of data.

Data Analytics and Decision Support Tools

Darnell and Barry (2017) and Skinner (2017) have explored in depth the issues around data availability, analytical capacity and reference architectures as part of the P2D project. This section references their work with specific regard to the economic benefit and business models of decision agriculture.

There are issues associated with appropriateness of decision-support analytics which are limiting the utilisation of decision agriculture technologies and practices. Fully-enabled decision agriculture require models and analytics with the ability to transform data into insights applicable to decision-making. For example, if data on pasture production for a farm that included imagery, soil moisture, soil type and species composition was available, the question becomes: do the appropriate analytics exist to use that data as inputs to predict feed availability in two months' time?

Significant challenges facing the concepts surrounding data analytics and decision support tools include: the variety in type and form of data collected on-farm/on-site; the changing knowledge and skill requirements by producers, service providers and agribusinesses to collect, store and analyse data; analytics capacity; business model functionality; data sharing and trust; and, uncertainty around what proposed Productivity Commission recommendations on 'Data Availability and Use' will mean for agricultural producers and supply chain participants.

A 'data lake' is generally much more valuable than a 'data silo'. The aggregation of several data sets can generate opportunities for more powerful data analytics, and increase the functionality of data sets to users. Currently, there are data silos within and across industries. As a result, producers face challenges accessing, integrating, and analysing data.

Compounding this challenge are a range of different data formats used by industry and government leading to interoperability challenges. This includes inconsistencies in operational procedures and policies governing the use of data e.g. currently there are a range of competing data systems architectures and data formats. In effect, this leads to issues with the interoperability of data, and as a consequence, the interoperability of digital products. For example, a farmer may be required to manually enter data into several separate mobile applications because they each have different data format/ system requirements. This undermines the functionality of digital technologies.

The interoperability of existing systems is a factor likely to impact the ability of new business and service delivery models for decision agriculture to emerge. As Skinner (2017) points out, most agricultural data tools and services have not been designed to share data. This has led to the creation of data silos with interoperability challenges. For producers, this can involve repeatedly entering the same data into many systems. The associated costs and efforts undermine the value proposition for using these tools and services.

Some form of data analytics capacity is required in order to achieve the bulk of the economic benefit estimated to occur as a result of unconstrained decision agriculture, for example in the Dairy sector 79% of the productivity gain that was modelled was the result of decision agriculture applications that required data analytics, likewise in the cotton sector 74% of the productivity gain modelled was dependant on data analytics capacity (*Table 5.1)*.

Summary

To facilitate the development of new business and service delivery models, major initiatives are required to improve several data analytics related issues, including:

- improving education and training around digital agriculture to increase the capability of users; and,
- resolving issues associated with different data governance approaches (e.g. inconsistent data systems architectures and ontologies) by government and industry service providers (i.e. RDCs).

Connectivity Infrastructure

Lamb (2017) has explored the connectivity issues limiting the acceleration of decision agriculture in depth in his review of on-farm telecommunications challenges and opportunities in supporting a Big Data future for Australian agriculture. This section references Lamb's findings with specific regard to the economic benefit and development of business models for decision agriculture.

Connectivity is a critical enabler of decision agriculture. A distinct difference between precision and decision agriculture is that the majority of processes involved in decision agriculture occur almost entirely online. A primary impediment to the adoption of precision agriculture has been the often-circuitous process required to collate multiple datasets in a single location for analysis. Decision agriculture instead uses cloud-based services and often remote connectivity to accumulate and analyse data.

Most decision agriculture products are reliant on full or partial (e.g. offline mobile-apps) internet connectivity. A lack of telecommunications connectivity can therefore directly negate a product's value proposition. While the value proposition might be recognised (i.e. the technology is known to lift profitability and deliver a return on investment through better decision-making), the product cannot be used due to poor connectivity.

The public focus on the 'data drought' in remote and regional areas has resulted in solutions moving beyond those which are being provided by the rollout of the National Broadband Network (NBN). Technical issues and service delivery problems, including poor upload speed, has prompted the rise of private information and communications technology (ICT) networks, such as district and farm-scale fixed wireless networks. While the many current barriers to connectivity are likely to persist for some time, a new generation of products designed to work in low-connectivity environments (i.e. sensors) are increasing in availability. However, much confusion and mixed messages from government and government agencies (e.g. Australian Competition and Consumer Commission (ACCC) and Productivity Commission) about the future of public investment in data connectivity infrastructure remains.

There are also major issues with telecommunications service delivery in rural Australia. This includes a lack of technical connectivity support for rural customers, and inflexibility in services and pricing policies (e.g. wholesale and off-peak usage).

Connectivity to the farm (e.g. homestead) and across the farm is critical to the uptake of digital technologies. Many of those who are connected to the internet are nevertheless constrained by slow data download and upload speeds. The issue of upload speeds is particularly important for agriculture given the rise of remote sensing and automation devices, which often require uploading data across significant distances.

Connectivity will also impact where the next wave of Australian AgTech innovations will occur. For example, entrepreneurs and technology developers in rural areas with poor connectivity infrastructure generally face much greater challenges than their counterparts in urban Australia.

Summary

To facilitate the development of new business models there needs to be major initiatives to improve several connectivity related issues, including:

- Collaboration between industry sectors on core telecommunications issues.
- Understanding (and mapping) total data usage requirements of producers, including diurnal and seasonal needs and business and lifestyle aspects of farming.
- Reviewing the potential of new technologies, particularly those designed for low-connectivity environments.
- Investigating the potential for public/ private investment models for funding telecommunications infrastructure.
- Industry stakeholders working with telecommunications service providers to review packages and policies for rural customers (e.g. wholesale and off-peak usage rates).

Trust and Legal Barriers

Wiseman and Sanderson (2017) have thoroughly examined the current and future state of data rules dealing with ownership, access, privacy and trust as part of the P2D project. This section covers issues explored in their paper with specific reference to the impact on economic benefit and business model development.

Adoption of decision agriculture is limited by many barriers, some of which are commonly associated with intangible factors such as trust and confidence. There are many questions regarding data ownership and control, particularly in terms of online data upload for analysis, that are yet to be fully addressed to the satisfaction of most producers. This is widely recognised as one of the most influential factors determining the wider adoption of decision agriculture.

Many Australian producers lack trust in service and technology providers when collecting and sharing their data (Zhang, Baker, Jakku, & Llewellyn, 2017). Furthermore, many producers are concerned about third parties gaining unauthorised access to their data. Their priority is to ensure that their data is kept private, safe and secure.

Producers generally have a poor understanding of the data licence agreements into which they are entering. There is a responsibility for agribusiness using standard form contract terms to ensure they are legible, transparent and fair. Greater transparency around terms of use that govern the aggregation, ownership, storage and dissemination of producers' agricultural data is needed prior to producers entering into commercial relationships with third-party advisers and technology service providers.

The current regulatory and legal framework surrounding the collection, use and exchange of agricultural data is complex and fragmented. Compounding this challenge is the need to keep pace with rapidly evolving developments in digital technology. The challenge for regulators is striking a "balance between providing a future-proof regulatory environment that adapts to the changing nature of technological advances and creating a level playing field, whilst also avoiding excessive burdens and protecting farmers' ownership and control of farm data as much as possible" (Copa-Cogeca, 2016). To keep pace with the digital era "public administrative authorities and all actors must therefore adapt faster than usual and provide the right tools to protect the specificities of the agricultural value chain" (Copa-Cogeca, 2016).

The Australian regulatory landscape is changing quickly. Currently, there is little or no legislation in Australia that deals specifically with data. The key consequence of this legislative vacuum is that the main way in which duties and obligations around data are set out is in private data contracts (or licensing) agreements. The Productivity Commission's final Data Availability and Use Report (2017) will, if implemented, have a fundamental impact on how agricultural data is managed in Australia. Open dialogue is needed between data contributors, data aggregators and industry stakeholders about the future management practices for data in the agricultural sector.

The absence of clear and consistent privacy principles, policies and frameworks within Australian rural industries has the potential to expose Australian producers to threats to their privacy, and to the security and safety of their agricultural data. This, in turn, limits the potential benefits that can be derived from digital agriculture and data.

An example of how legal and trust issues are impacting the adoption of digital agriculture is through the 'right to repair' issue. A number of agricultural-technology providers encrypt their digital farming software. This restricts the ability of producers to access software that would provide them with diagnostic and repair information about their farm machinery. In turn, this prohibits producers from attempting to repair or modify their machinery.

The complex nature of data management systems implies an inherent requirement for collaboration between industry representatives, service providers (i.e. RDCs) and government is needed, to ensure that a legal framework protects the specificities of agricultural data. Despite wide-spread inter-industry and cross-sectoral belief that data produced on-farm/site should be owned by the producer themselves, it has been established that data cannot necessarily be owned in the same way as physical assets, meaning that there is a need for key principles on access to agricultural data and usage rights.

Collaboration between producers and agribusinesses is needed to address trust issues and facilitate greater uptake of digital agriculture. A genuine two-way relationship between agri-businesses and Australian producers is needed to facilitate their continued willingness to supply their agricultural data. To achieve this, third-parties and agribusinesses should ensure that their terms governing data are more transparent and available, and that this is communicated to producers.

Summary

Legal and trust issues associated with agricultural data are emerging as a critical challenge for Australia's agricultural industries.

To facilitate the development of new business models there needs to be major initiatives to improve several data related issues, including:

- Clarifying data ownership, control and access issues – including potential barriers posed by Intellectual Property (IP) regimes such as copyright, the current contractual practices that regulate data ownership, control and use of agri-data and, importantly, the 2017 Productivity Commission review into data availability and access;
- Improving data privacy, safety and security – which raises issues of privacy, confidentiality and contracts; and
- Ensuring data is transparent and trusted – which raises issues of industry guidelines (e.g. US Farm Bureau, NZ Dairy) and contracts (open and transparent).

Value Proposition

A clear value proposition, including tangible economic benefits, is needed to encourage users to adopt decision agriculture technologies and practices. Similarly, it is also a critical factor affecting the development of new businesses models.

A value proposition defines the kind of value a company will create for its customers. Developing a unique or novel value proposition involves finding a new way of segmenting or expanding a market.

Professor Michael Porter from the Harvard Business School suggests there are three fundamental questions that a business must answer to develop an effective value proposition (*Figure 5.1*):

- Which customers are you going to serve?
- Which needs are you going to meet?
- What relative price will provide acceptable value for customers and acceptable profitability for the company?

In many cases, one of these questions becomes the primary focus for determining the value proposition.

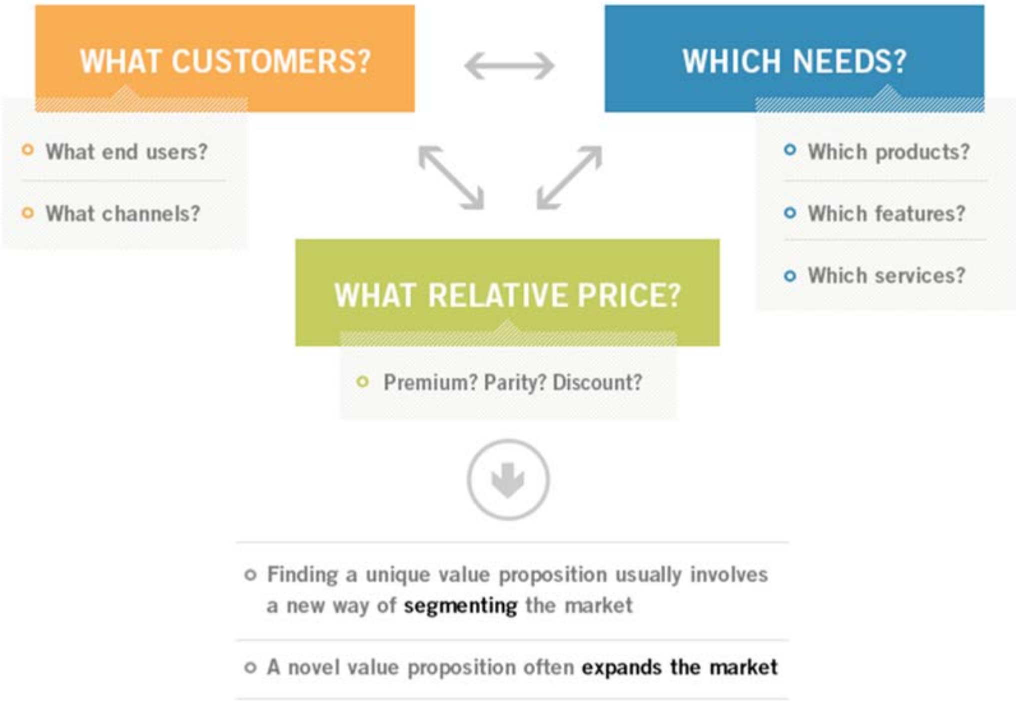


Figure 5.1 Key questions for defining a value proposition. (Source: Harvard Business School, 2017)

Business development strategy for many companies, is built around their ability to meet a particular need or a subset of needs. This means that the development of a value proposition commonly involves first identifying the customer profile. A company must identify the target end users of their product(s) or service(s), and the channels through which they intend on reaching them, subsequently leading directly to the next questions related to identifying user needs and the relative price point in comparison with competitors.

Some value propositions target customers who are overserved (and hence overpriced) by other offerings in the industry. A company can win these customers by eliminating unnecessary costs and meeting 'just enough' of their needs. Where customers are overserved, the lower relative price is often the dominant question. Conversely, some value propositions target customers who are underserved (and hence under-priced) by other offerings in the industry. These customers want an enhanced product or service and are willing to pay a premium for it. The unmet need is typically the dominant question, while the higher relative price supports the extra costs the company has to incur to meet it.

Interestingly, there are many intangible value propositions that were suggested during the industry workshops and a consensus that these are just as important to communicate; Decision agriculture should:

- Provide a benefit to lifestyle, social outcomes and feel good factor.
- Make farming easy so you can sleep well – technology should value time and be fun.
- Should provide a community benefit in promoting agricultural provenance.
- Involve a value proposition deliverable through consistency of service and support, and the reliability of technology – It needs to work or value will be eroded quickly.

- Identify many farmer advocates before a value proposition communicated by sales will be trusted and supported.
- Involve a value proposition that recognises that decision agriculture does not come in a box, however has multiple players e.g. service provider, agronomist, consultant, grower, i.e. need to ensure that human resources are considered in parallel with technology.
- Include a greater proportion of value gained than the perceived loss of control of data.
- Deliver a 'recipe' for implementation.

Summary

A clear value proposition is critical to facilitate the utilisation of decision agriculture and encourage the development of new business models.

There are a number of factors emerging as critical to developing a tangible value proposition for decision agriculture;

- The need for a commercial proof of outcome, including an increase in productivity dollars.
- The value proposition can be provided through industry benchmarking and on-farm validation.
- The need for the value proposition to demonstrate a financial return that is either increased quality and/or yield and reduced cost.
- The value proposition includes helping manage risk (e.g. improving confidence in decision-making).
- Value propositions providing whole-of-industry benefits (national) will only be delivered if farm scale value is demonstrated (i.e. Big Data is made from lots of small data).

Summary: The Impact of Current Constraints on the Realisation of Decision Agriculture

All of the constraints that are preventing the development of decision agriculture are interrelated and dependant on each other. *Table 5.1* displays the proportion of total productivity gain for each sector that decision agriculture will deliver that is dependent on each of the constraints described above being resolved.

Table 5.1 The proportion of productivity gain impacted by decision agriculture constraints (%).

Sector	Data[1]	Analytics[2]	Connectivity[3]	Trust[4]
Rice	65	68	90	90
Grains	78	79	82	81
Cotton	88	74	75	98
Sugar	65	91	73	73
Horticulture	79	98	98	99
Beef	85	85	100	85
Sheepmeat	66	92	100	74
Wool	66	92	100	74
Pork	86	100	85	86
Dairy	64	79	84	64
Eggs	65	53	82	53
Chicken Meat	53	86	61	67
Wine	85	94	100	91
Forest and Wood Products	24	78	33	33
Livestock Exports	61	61	100	100
Red Meat Processing	61	87	61	61
Fisheries and Aquaculture	89	89	100	100
Average	**70**	**83**	**83**	**78**

[1] The proportion of estimated overall productivity gain that relies on technology requiring public or multiple data sets.
[2] The proportion of estimated overall productivity gain that relies on data analytics capacity.
[3] The proportion of estimated overall productivity gain that relies on online connectivity.
[4] The proportion of estimated overall productivity gain that relies on sharing data or data sets amongst multiple participants.

For example, in the Rice sector 65% of the productivity gain that has been modelled is dependent on multiple data sets being available and accessible, 68% is dependent on data analytics capacity, 90% is dependent on online connectivity and 90% on sharing multiple datasets. The percentages have been calculated by determining which of the technology shocks imposed for each sector (described in detail in *Appendix 2*) requires either multiple data sets, data analytics capacity, online connectivity or sharing of data and then calculating the productivity gain from those shocks as a proportion of the total estimated productivity gain as measured by GVP increase.

The figures in the table demonstrate that total productivity gain is dependent on all barriers being resolved. While the average for all sectors show that slightly more productivity gain is dependent on analytics capacity and connectivity (both 83%) than trust (78%) and data (70%), the high numbers illustrate that each barrier acts as a critical impediment to full development of decision agriculture.

In other words, to support the acceleration of precision agriculture to decision agriculture, there must be initiatives that simultaneously target each barrier. Furthermore, these actions must acknowledge the complex interaction between each of the barriers e.g. to effectively resolve data analytics issues (such as the interoperability of different databases) requires at the same time improving connectivity infrastructure, the underlying foundational datasets, and minimising trust and legal issues surrounding data sharing.

The value proposition for decision agriculture will remain substantially as potential rather than delivered until these constraints are addressed. Fortunately, as the potential is understood to be significant (as demonstrated in the economic analysis section of this report), there is considerable pressure to resolve each constraint.

This pressure is being expressed through commercial and market activity (particularly in the field of telecommunications infrastructure) and policy and strategy development from governments and research funders. Resolving each of the constraints described above will result in a marketplace where decision agriculture product developers and service delivery providers will be able to participate to provide solutions which deliver tangible value to agriculture.

Conclusion and Recommendations

Decision agriculture has the potential to fundamentally transform the way food and fibre is produced, traded and consumed. The digital technologies that inform decision agriculture are allowing objective information about soil, water, crops, pasture, animals, weather and other areas to be quickly collected and analysed for decision-making. Decision agriculture provides information, and ultimately knowledge, that leads to decisions being made with a higher degree of precision than has been feasible in the past.

This project is primarily focused on how technology and data impact on-farm decision-making. However, it also recognises that many of the biggest drivers for decision agriculture will occur at other points in the supply chain. There are many 'push' and 'pull' factors influencing how farmers, processors, retailers and other businesses utilise data and technology to improve decision-making and business profitability. The structure of the supply chain, including the size of businesses and the level of business integration between production and retail stages, have significant effects on the potential for decision agriculture.

The size of the opportunity that decision agriculture presents was estimated using the Centre for International Economics (CIE), Food Processing general equilibrium model of the economy. A ‘fully enabled’ decision agriculture is estimated to grow the value of agriculture in Australia by $20.3 Billion (a 25% increase on 2014–15 levels) and the Australian economy by $24.6 Billion (a 1.5% increase on 2014–15 levels). The considerable benefit from decision agriculture will be delivered through transformation of value chains and will require cross-sectoral coordination of enabling infrastructure, policy and investment.

Recommendation: Australian agriculture digital strategy.

The fifteen Research Development Corporations (RDCs) should collaborate to develop an Australian agriculture digital strategy and implementation roadmap for cross-industry digital enablement [and to support the expansion of shared services] (D2D CRC Recommendation 3). The strategy should focus on core challenges such as:

- Telecommunications infrastructure
- Data Governance
    - Technical issues e.g. industry data standards, data security definitions, and data systems architectures
    - Legal issues e.g. the creation of a Data Code of practice, a data certification or accreditation scheme, and data licensing access and licensing arrangements.

Recommendation: Cross-sectoral collaboration.

The Federal Government in collaboration with the Council of RDCs should investigate options to incentivise cross-sectoral collaboration between RDCs (including reviewing the future of the Rural R&D for Profit program beyond 2021–2022). This includes supporting multiple-RDC initiatives around strategic issues such as digital agriculture.

Recommendation: Sector-based digital strategies.

RDCs should each develop an industry Digital Strategy (as in Meat & Livestock Australia's Digital Value Chain Strategy) and commit resources to its implementation, for example through the employment of a Chief Agricultural Data Officer or equivalent (c.f. D2D CRC).

Most decision agriculture applications will continue to relate to production based practices even if the data informing those practices is coming from beyond the farmgate. There are some implications of decision agriculture however which will lead to (potentially substantial) indirect benefits. Issues such as biosecurity monitoring and regulatory compliance for food safety are critical whole of agriculture issues that will require an industry (and government) response.

Recommendation: Biosecurity

It is recommended that RDCs, governments and industry bodies (including biosecurity agencies) review the potential for cross-sectoral digital platforms and technologies to improve the efficiency and delivery of biosecurity management activities, including surveillance and monitoring, communications, and industry emergency response activities.

Recommendation: Improved regulatory compliance.

Regulatory compliance is a major cost to producers and businesses across the supply chain. Currently, many compliance systems still rely on traditional paper-based reporting across multiple platforms. It is recommended that the fifteen RDCs in collaboration with Australian governments and agencies review options to digitise and automate regulatory compliance activities with the aim of consolidating the number of platforms required (including data collection, storage, reporting etc.).

There are many barriers and constraints which are currently preventing the opportunity that decision agriculture presents from being delivered in full. The research reported on here, and the broader P2D program, has been designed to investigate the barriers and constraints that are limiting the realisation of the potential benefit of decision agriculture. Recommendations from this report are intended to guide ongoing investments and coordinated action in areas that are likely to accelerate the shift from precision agriculture to decision agriculture.

At the heart of decision agriculture is the analysis of data leading to better informed decision-making. Most of the productivity shocks that were applied to the CIE-Regions FP model are dependent on analysed data. Aggregating and analysing data to some extent is what defines decision agriculture as being different from precision agriculture, however, it is also where much of the frustration of digital agriculture technology has been experienced.

Even where there are no connectivity limitations (addressed later in this section) there remains significant technical barriers to collecting and analysing data from multiple sources. These barriers are almost universally whole of agriculture issues and the following recommendations are proposed accordingly as multi-sectoral responses.

Recommendation: RDC collaboration on agricultural data.

It is recommended that the fifteen RDCs work collaboratively to develop consistent approaches to data policies and operational procedures (e.g. data formats, systems architectures etc.) that will improve the interoperability of data sets.

It is recommended that the fifteen RDCs work collaboratively to review opportunities to share data sets, data tools, and associated services.

Recommendation: Foundational Data Sets.

It is recommended that the fifteen RDCs collaborate to establish a set of Foundational Data Sets for cross-industry use. There are several core or foundational data sets which form the basis of public and private sector digital agricultural systems.

Australian governments should invest in addressing gaps in foundational data sets, particularly for soil mapping and weather recording stations. This includes investigating the potential for public/ private investment models and the integration of privately collected data into the soil and weather/ climate datasets that form an essential foundation for digital agricultural systems.

RDCs should regularly review the functionality and user experience of existing data and decision support tools in order to ensure their effectiveness and drive adoption.

Recommendation: Open Access to Data

It is recommended that Australian agricultural industries, agricultural technology providers and digital agriculture platforms and software system providers collaboratively develop a strategy regarding open access to data. The strategy should include a review of the use of open access protocols in North America and Europe.

Of course, a major and often talked about barrier to implementing decision agriculture is the poor state of rural and regional connectivity. The majority of decision agriculture applications require at least partial online connectivity, and some are based entirely on the internet. It is not just having any connectivity that is important either. High speed, high capacity connections are critical due to the quantity and types of data that need to be uploaded for analysis.

International markets that are more advanced in decision agriculture implementation are generally supported by better connectivity than is experienced in most of rural and regional Australia. While there is an accelerating amount of commercial activity providing on-farm solutions there are still many critical infrastructure bottlenecks and policy impediments preventing improved connectivity.

Recommendation: Improving Connectivity.

A lack of access to mobile and internet telecommunications infrastructure is a major impediment to the adoption of digital agricultural systems. Furthermore, it is costing producers, agribusinesses and the Australian economy billions of dollars each year in terms of lost productivity (and profitability). Given the common telecommunications challenges faced by all agricultural sectors (including forestry and fisheries), a multi-sectoral response is needed.

It is recommended that the fifteen RDCs, under the guidance of the Council of RDCs, establish a joint Telecommunications Taskforce. The objective of the Taskforce will be to oversee mobile telecommunications development and execution strategies aimed at national coverage, including equitable access in rural and regional areas and future proofing (e.g. speed/volume) in light of changes in usage (e.g. connected devices on-farm) and growth and complexity in web based services available to producers (University of New England). The Taskforce should work closely with telecommunications technology and service providers, governments, and the National Broadband Network (NBN).

In addition, the fifteen RDCs, in collaboration where possible, should focus their investment on:

- Understanding (and mapping) total data usage requirements of producers, including diurnal and seasonal needs and business and lifestyle aspects of farming.
- Reviewing the potential of new technologies

It is recommended that Australian governments increase available funding to augment on-farm telecommunications. In addition, the following actions should be undertaken:

- Investigate the potential for public/ private investment models for funding telecommunications infrastructure. This includes reviewing mechanisms to support small and medium sized telecommunications providers e.g. regional fixed wireless network providers.
- Review the Universal Services Obligation (USO) to formally recognise that the needs of rural and urban businesses differ. The USO definitions should be updated to acknowledge the importance of data 'speed', beyond the current narrower focus on data access.
- Review options to deliver multi-point connectivity to farms and rural businesses.

Even when all the technical and infrastructure barriers have been removed there remains a cultural barrier to the full implementation of decision agriculture. Before data can be aggregated and analysed to deliver insights for improved decision-making, a producer has to make the decision that they are comfortable with providing their data to be analysed. The CSIRO producer survey conducted as part of the P2D project determined that most producers are not comfortable with sharing data and in many cases, are worried that others are deriving more value from their data than they are (Zhang et.al., 2017).

Farmers globally, are concerned about sharing agricultural data and there are initiatives underway in countries such as the United States (US) and New Zealand (NZ) which are attempting to provide an industry response to better data practices. Industry responses and strategies for good data practice are required before the confidence required for farmers to share data to enable decision agriculture is developed.

Recommendation: Trust in data practices.

Australian agriculture should work towards developing a clear and consistent national voice in relation to developing understandable, ethical and efficient agricultural data practices.

In the absence of a new multi-RDC Taskforce, it is recommended that the National Farmers' Federation consider the merits of the creation and implementation of a voluntary Data Code of Practice that would set out standards for ethical and transparent data practices that advisers and agribusinesses must meet when providing services to producers. In signing up to the Data Code of Practice, advisers and agricultural providers would agree to act in an ethical and transparent manner in all their data dealings with Australian producers (see Griffith/ USC Recommendations). The review should consider relevant developments from the United States (US) (e.g. Open Agriculture Data Alliance), New Zealand (NZ) (e.g. NZ Farm Data Code of Practice) and other international case studies.

Recommendation: Building trust in digital value chains.

Collaboration between producers, agribusinesses and government is needed to address trust issues and facilitate greater uptake of digital agriculture.

The benefits of digital agriculture must be shared by businesses across the value chain. Organisations that benefit from agricultural data generated on-farm (including processors, advisors, machinery/ technology providers, and input suppliers) should acknowledge a responsibility to ensure farmers also benefit from the data.

Greater transparency around the terms of use that govern the aggregation, ownership, storage and dissemination is needed prior to producers entering into commercial relationships with third-party advisers and technology service providers. Third parties and agribusinesses should ensure their terms governing data are easily accessible, legible, transparent and fair.

Government and industry stakeholders should investigate the need for legislation that outlines how agricultural data is managed. As a default position, producers, and other suppliers and consumers of data, should have the right to be notified if their data is traded.

More confidence in data sharing will deliver added benefits to the agricultural community that extend beyond insight for on-farm decision-making. Research gaps and requirements can be better informed through objective information about agricultural practice and production. There is also the capacity to have far more accurate information on industry and sector statistics than is currently provided through traditional surveying methodology.

Recommendation: Improving the agricultural census.

Australian government agencies, including ABARES, should evaluate the potential to incorporate alternative data sources into the national agricultural statistics system. Alternative data sources could supplement or replace traditional data sets (and collection methods) and enhance the robustness and relevance of agricultural statistics. A comprehensive review should be undertaken in a timely manner to inform the design of the next agricultural census.

The technologies that enable decision agriculture are evolving rapidly resulting in a transformation landscape that is fast paced and confusing. Producer understanding of the potential of decision agriculture, research funding strategy for decision agriculture, and the provision of technical support and backup for the technologies involved are all struggling to keep pace with the change that is occurring.

Education and training packages are required at all levels within the industry to upskill existing knowledge. Entirely new programs should also be developed to provide the new agricultural workforce that will be required to progress decision agriculture.

Recommendation: Education and training.

To support the adoption of digital agriculture RDCs should work with farmer groups to develop educational packages, including case studies illustrating on-farm telecommunications technology options for their stakeholders (refer to UNE report). This includes use cases for high-value applications of decision agriculture. As part of their education and extension strategy, RDCs should also consider establishing producer demonstration sites to showcase on-farm decision agriculture applications.

It is recommended that the fifteen RDCs, in conjunction with education and training providers, review the skills needs required by producers to effectively utilise digital technology.

Recommendation: Extension.

Private sector digital agriculture applications and platforms have the potential to dramatically change the way in which farmers access production and other information relevant to farm management decisions. These systems will become the principal information supply chain for farmers in the future. RDCs and government agencies should develop new strategies that recognise these systems as the principal extension pathways of the future.

Decision agriculture products and services will be delivered through new and evolving business models and platforms alongside traditional established agribusinesses and publicly funded research and government organisations. It will be a complex environment that will require an understanding of business development approaches that may not be traditionally associated with agriculture.

One of the more exciting aspects of decision agriculture is that the potential that it represents is attracting interest and participation from new entrants to agriculture. Renewed interest in agriculture as a career path is being observed and business opportunities being explored. In order to harness the skills that these new entrants bring for the benefit of agriculture the following recommendations are made.

Recommendation: Role of private sector.

RDCs have a fundamental role in the generation of knowledge to underpin digital agricultural applications, but should not lead the development of software programs or digital agriculture platforms to be used by farm service organisations or farmers. It is the role of the private sector to develop digital agriculture software programs and platforms.

Recommendation: Partnerships and private sector engagement.

It is recommended that the fifteen RDCs investigate new partnership and funding models to support innovation in digital agriculture. This includes considering opportunities to encourage entrepreneurial private sector activities and start-ups through incubators, accelerators, cooperative research centres (CRCs) etc. Understanding of lean and agile business methodologies will be required in order to achieve this.

The development of decision agriculture is occurring globally. Some countries, particularly those with large market size and fewer barriers, have thriving AgTech investment environments and a more mature market for decision agriculture applications than Australia. Many of the technologies and applications developed internationally have applicability in Australia and should be investigated for their potential.

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Appendix 1. The Centre for International Economics Food Processing General Equilibrium Model of the Economy

The current contribution of agriculture (and food processing) to the Australian economy

The CIE Food Processing Model describes the whole value chain of an agricultural product from production to manufacturing, marketing and consumption.

The model is based on actual Australian data (ABS Input and Output tables) that captures the individual nature of each agrifood value chain. The model accounts for market behaviour affecting supply and demand between farm, processors and consumers for fresh and processed products. It includes farming, transport, handling, wholesaling, manufacturing, marketing, retailing, taxes and trading (imports and exports).

In the model, input use is broken down into thirty-eight sectors and a production function explains the relationship between input use, substitution between inputs and output from each sector. Responses depend on cost of inputs, price of outputs and the level of relative technical efficiency between inputs and outputs.

Figure A1.1 below illustrates the aggregate data representing Australia's agrifood value chain, and constituted the base scenario for the economic modelling conducted (representing 2014–15 figures).

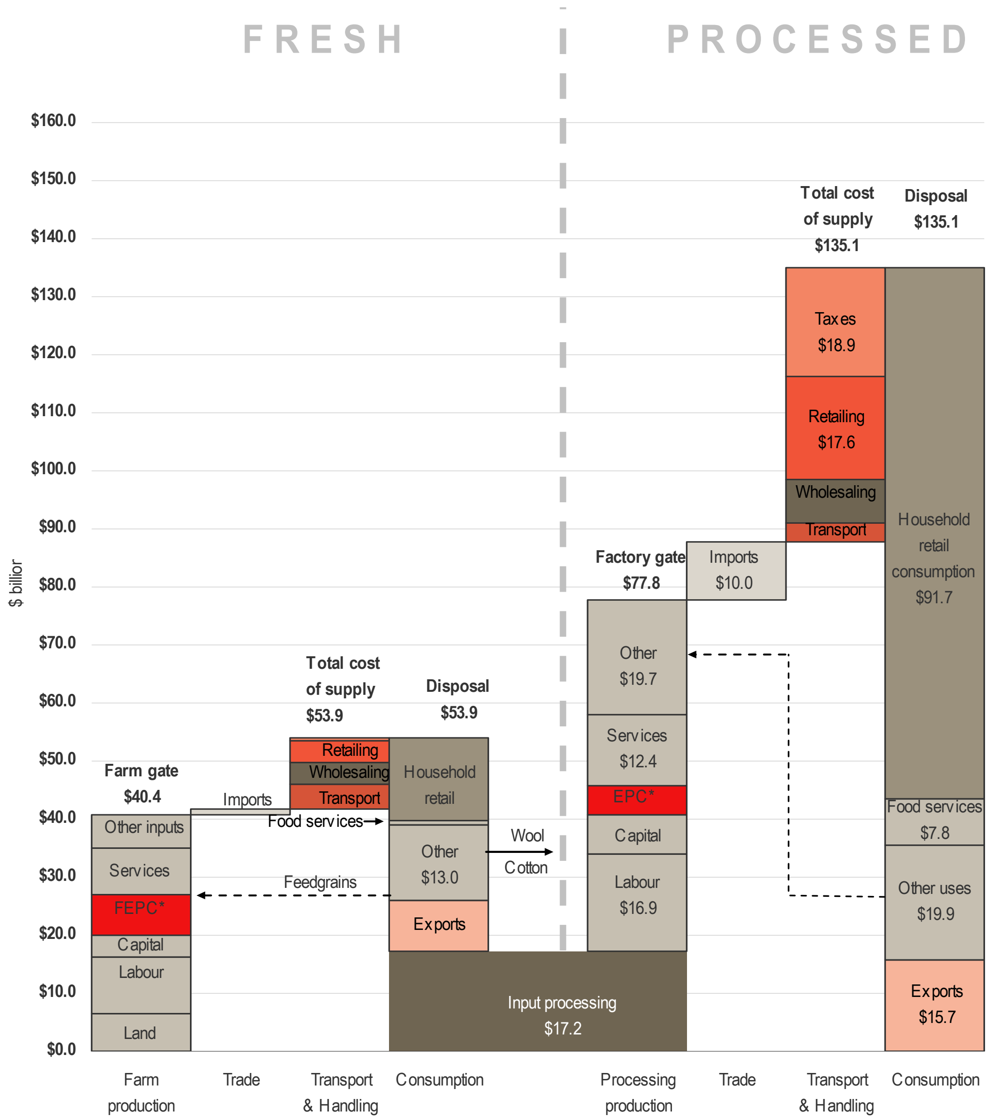


Figure A1.1 Aggregate value chain data for Australian agriculture and food processing. CIE estimation based on ABS and ABARES data.

The Australian agricultural food production value-chain is currently valued at approximated $170 Billion per year. Around 30 per cent of this value originates from farming production, while 70 per cent is associated with the manufacturing (processing) and distribution process.

Processing derives most of its inputs from sectors outside of agriculture. Agricultural production contributes around 32 per cent to processing, or around 22 per cent of the total factory-gate value of processed food. Household and food service consumption of food is predominantly in processed form, and Australia exports more processed food than unprocessed agricultural products.

The farm-gate gross value of production figure, AUD$40.4 Billion, considers primary factor inputs (land, labour and capital) and intermediate inputs (fuels, fertilisers, pesticides etc.) that for the most part, are products derived from other industries in the economy. There is a small proportion of imports, with margin activities (transport, wholesale and retail trade) added to the farm gate value to provide a wholesale and/or retail value of fresh produce worth approximately $53.9 Billion a year.

A proportion of the $53.9 Billion of agricultural production is consumed directly as fresh produce by Australian households, particularly fruit and vegetables, while others such as feed grains and seeds are recycled back to agriculture; and some non-foods, e.g. wool and cotton, are used as inputs for other industries.

Determined primarily by domestic and international prices, approx. 20 per cent of Australian agricultural output is exported unprocessed (e.g. wheat), while the remainder, approx. 32 per cent, is used as inputs by food processing industries. In addition to fresh inputs, those from other industries, and primary factors, generate a factory-gate value of $77.8 Billion of processed food products per year.

Imports and other margin activities of transport, wholesaling, retailing and taxes are added to the $77.8 Billion to provide a retail and/or wholesale value of processed products of $135.1 Billion.

Approximately $99.5 Billion is purchased by households, and food service outlets and restaurants in Australia. Some $19.9 Billion is recycled within the food processing sector, ie. meat intended for use in meat pies, and cheese in pre-packed pizzas, as well as other non-food sectors. The remaining 12 per cent (approx.) is exported.

The description above outlines the value chain for all of agriculture. Individual sectors will potentially have quite different value chains depending on how much product is consumed raw or processed, or how much is consumed domestically rather than being exported.

Figure A1.2 illustrates the approximate breakdown of GVP across the value chain for the beef, dairy, wheat, flour and bakery; and horticulture industries. It indicates the position(s) in the value chain where benefits from changes in productivity are likely to occur. For example, a change in on-farm productivity in the beef sector is likely to lead to a substantially larger increase in productivity in the processing sector. In contrast, in the grains industry, a large proportion of the benefits of on-farm productivity are likely to be captured within the farm-gate.

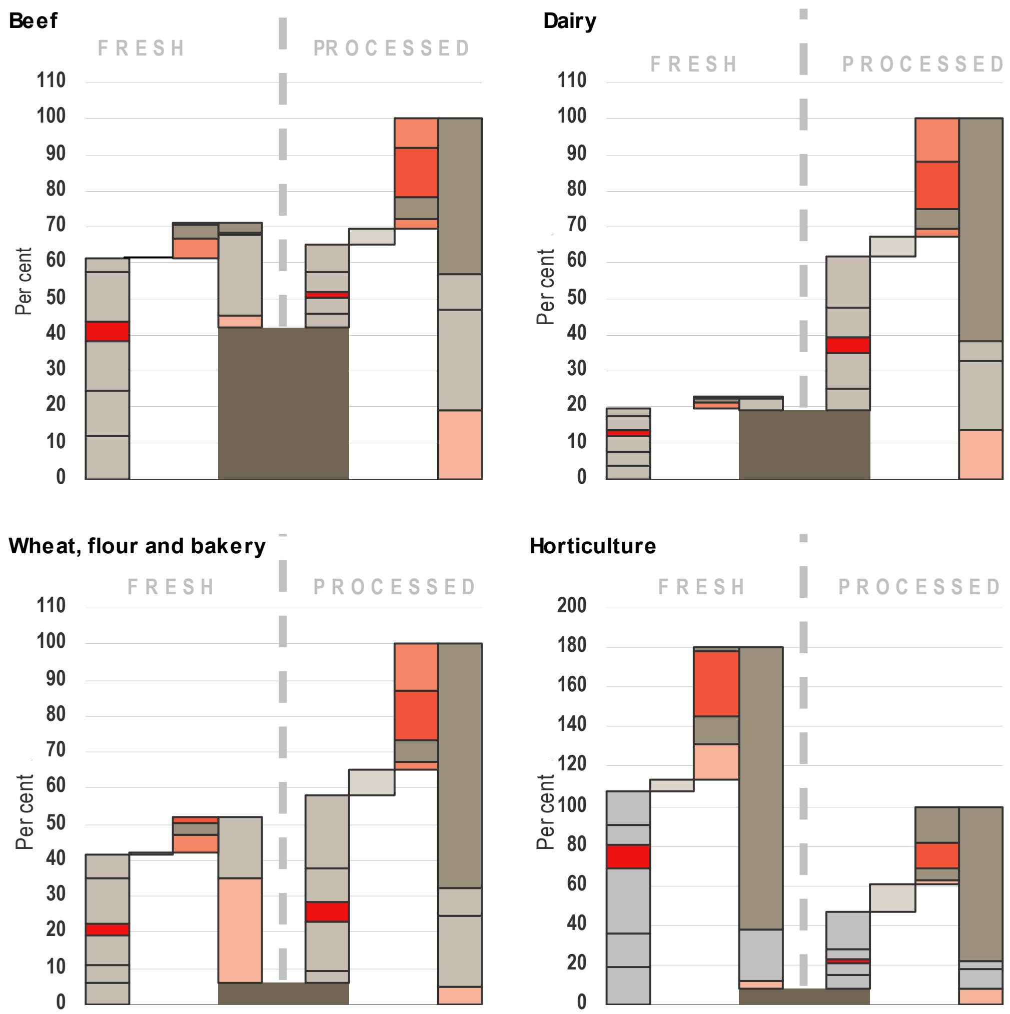


Figure A1.2. Schematic differences in value chains between agricultural products.

Modelling the impacts of productivity improvements

To determine the effects of a practice change that leads to a productivity boost, a series of ‘shocks’ were applied to the model. A shock essentially describes a scenario. For example, a shock for the grains sector might involve the adoption of a decision agriculture practice that results in 10% less fertiliser being used for the same yield. The model then estimates the aggregate economic effect this has on the gross value of production (GVP) in the grains sector and the overall impact on the gross domestic product (GDP) of the Australian economy – including for example how inputs (i.e. fertiliser) are reallocated to other sectors of the economy.

In general, technological progress can be categorised into two types of impacts:

- Demand-side impacts: induced change in consumer preference such as switching to a more healthy diet and lifestyle; development in export potentials.

- Supply-side impacts: more efficient use of inputs to produce existing products; development of new characteristics and uses for existing products; invention of new products; higher labour productivity of a healthier population.

In most cases a single practice change may have both demand and supply-side impacts. For example, switching to healthy diet and life style is a demand-side impact initially, but over time this switch would improve health of the general population, leading to productivity improvement which is a supply side impact.

Sometimes perceived demand-side impacts are actually due to supply-side outcomes. For example, customers are willing pay a price premium for a product. In the first instance, it looks like a demand-side impact. However, in fact it is because of supply side changes. The price premium is the value of new characteristics and/or new functionality the product provides and the consumers are willing to pay.

On the other hand, supply-side outcomes will certainly have demand side impacts. For example, a new technology to increase the efficiency of producing a traditional product will reduce the cost of the product, leading to higher demand domestically and abroad. More generally, new inventions will lead to higher productivity and higher income, and thus higher demand.

For the above reasoning, in this study the impacts of technology adoption and practice change were modelled primarily as supply-side shocks, e.g. productivity changes. The general principles to derive the shocks are:

- If there is a cost reduction, the productivity shock is calculated directly from the cost reduction for the relevant inputs.
- If there is an anticipated price premium for a product, the productivity shock is derived from the price premium net of additional costs.
- If there is an anticipated growth in domestic or export demand for a new product, the productivity shock is calibrated such that the anticipated growth in demand is achieved.
- Similar to the above market growth, if there is an anticipated growth in production of a new product, the productivity shock is calibrated such that the anticipated growth in production is achieved.

In some cases, impacted products are only parts of a sector identified by the Food Processing Model, for example, cheddar cheese is a component of the dairy manufacturing sector. We use the size of the product to scale the productivity shock so that it can be appropriately imposed on the parent sector.

Economy-wide impacts

As a general equilibrium model, the Food Processing Model is able to link changes in one sector to the wider economy through price signals and goods and services flows. As such, the benefit of a practice change is not just benefits of the directly impacted sector/product, but the benefits to the whole economy. One measure of such benefits is the change in household real consumption. In a general equilibrium model, it measures ultimate welfare change of a society after accounting direct and indirect impacts.

Typically, a productivity improvement in a sector will boost the sector. The reduction in cost, or in the price premium case where higher quality or new functionality is achieved with similar costs, enables the producer/s to offer lower price of their products to induce more demand from domestic customers and exporters. The outcome, or in modelling terms the new equilibrium, will be higher production and cheaper price.

The boost in the directly impacted sector will have various effects on the rest of the economy. The cheaper price of the sector/product will further reduce the input costs of other sectors which use the direct impacted products, which in turn enhance the competitiveness of their products, boosting those sectors too.

On the other hand, some sectors may contract due to productivity improvement in one sector. For example, if a technology improves the yield of cheddar cheese, the demand for raw milk may fall because less milk will be required to produce the same amount of cheese. If the expansion in the cheddar cheese market is not big enough, that is the expansion (growth in production) is less than the productivity improvement, the net demand for milk will be smaller.

If the expansion is bigger than the productivity improvement, the sector will demand for more inputs to facilitate the expansion, leading to expansion in those sectors providing inputs to the directly impacted sector. However, the higher demand from the sector may have adverse impact on other sectors that compete for resources. For example, under a full employment scenario, higher demand for labour will push up labour costs, and thus depressing those sectors without adequate growth in demand and/or productivity improvement.

Overall, the expansionary effects of productivity improvement outweigh the contractionary effects for the whole economy. The total economic activity will be higher, as measured by the gross domestic product (GDP). So is household consumption, which measures the overall gain of the evaluated R&D outcome.

Other macroeconomic indicators may not necessarily move with household consumption. For example, although productivity improves the competitiveness of domestic products, leading to higher exports, the imports may increase as well because of higher income. Moreover, some products may divert from exports to domestic market to fulfil higher domestic demand by households and industries. As a result, the net exports (exports minus imports) may fall along with higher GDP and consumption.

Appendix 2. The Economic Impacts of Decision Agriculture by Sector

The following section presents the findings from the economic modelling of the potential benefits of decision agriculture to each Australian agricultural sector (including forestry and fisheries). This includes a discussion of the impact of current constraints (e.g. connectivity) and the implications for the likely development of business models for decision agriculture products and services.

As discussed in the methodology section it is important to remember that the shocks applied to the CIE model estimate the size of the opportunity under a best-case scenario. How much of that opportunity is realised is highly dependent on an array of factors and may differ significantly between sectors.

The table below outlines the relevant sectors (and their supporting RDC) covered during the P2D project.

Table A2.1: Sectors covered by the P2D project and their relevant RDC.

Sector	RDC
Rice	Rural Industries Research and Development Corporation
Grains (including oilseeds and pulses)	Grains Research and Development Corporation
Cotton	Cotton Research and Development Corporation
Sugar	Sugar Research Australia Limited
Horticulture (leafy greens, brassicas, and carrots)	Horticulture Innovation Australia Limited
Beef	Meat and Livestock Australia
Sheepmeat	Meat and Livestock Australia
Wool	Australian Wool Innovation Limited
Pork	Australian Pork Limited
Dairy	Dairy Australia Limited
Eggs	Australian Egg Corporation Limited
Chicken Meat	Rural Industries Research and Development Corporation
Wine	Australian Grape and Wine Authority
Forest and Wood Products	Forest and Wood Products Australia
Red Meat Processing	Australian Meat Processor Corporation
Livestock Exports	Australian Livestock Export Corporation Limited (LiveCorp)
	Fisheries Research and Development

Rice

Sector Overview

The Australian rice industry is well situated to benefit from developments in decision agriculture, particularly in technologies and services that increase water use efficiency.

Australia is a very small rice producer by global standards (2% of the global trade), but is a significant exporter of high quality medium rice varieties (25% of the global trade) (Ricegrowers' Association of Australia).

There was a major reduction in the size of the Australian rice industry during the Millennium droughts. Since then, the annual area of rice planted has hovered around the 80,000ha mark (Ricegrowers' Association of Australia). However, there has been a strong increase in rice yields per hectare.

The major player in the Australian rice industry is SunRice (Ricegrowers' Limited), a cooperative owned by ricegrowers, which is involved in rice processing, packing and marketing activities. The cooperative nature of the rice industry could potentially facilitate the development and uptake of decision agriculture.

Production

A number of rice production factors can be readily addressed through the implementation of decision agriculture.

The vast majority of Australia's rice production is in the Murrumbidgee Irrigation Area NSW, the Coleambally Irrigation Area NSW, the Murray Valley of southern NSW, and northern Victoria. Rice production in these regions is entirely dependent on the availability of irrigation water.

There are approximately 1,500 rice farms in southern Australia growing 80,000 ha of rice. The area of rice planted each year varies significantly due to seasonal factors, including the availability of water. Prior to the Millennium drought, when water allocations allowed, between 120,000–160,000 hectares were sown to rice in October of each year across this region, producing an average of around 1.2 Million tonnes annually (Ricegrowers' Association of Australia).

In 2014–15, an area of 69,700ha was planted to rice, yielding 690,400t (Savage, 2016). The industry has the capacity to produce over 1m tonnes annually. Australian rice production has declined significantly from the early 2000's due to reductions in irrigation water entitlements. However, productivity has increased. The yield per hectare has increased from 8–9t/ha in the 1990's and early 2000's to over 10t/ha (e.g. 10.9t/ha in 2013–14).

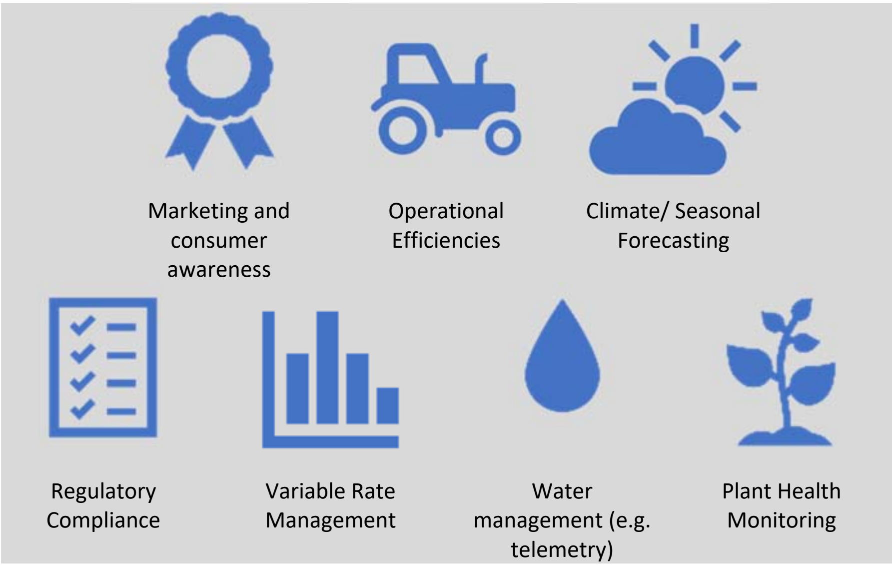
Rice growing is highly regulated and the crop can only be grown on approved soils and in compliance with irrigation company policies. The Australian rice industry is a world leader in water use efficiency and has targeted water productivity of 1 tonne of rice per megalitre (ML) of irrigation water.

The rice industry typically generates a Gross Value of Production of $800 Million per year. Rice growing, milling, value adding and transportation is regionally significant; directly employing 8,000 people in the Riverina and a further 37,000 people in flow-on activities (SunRice).

Rice consumption

SunRice estimate that Australian rice feeds more than 20 Million people each day. Domestic consumption of rice has increased from around 2 kg per capita in the late 1970's to 15.4 kg per capita in 2013 (ABARES 2014). In recent years there has been strong growth in rice consumption through the food service and food processing sectors. Increased rice consumption is consistent with an increase in Australian consumption of Asian style cuisines. Australia imports a range of specialty rice varieties. In 2015–16, $210m worth of rice was imported (Savage, 2016). Over the past five years (2011–12 to 2015–2016) the value of both rice imports and exports have increased. In most years, Australia is a significant net exporter of rice.

Key Drivers of Decision Agriculture



There has been considerable uptake of precision agriculture in the rice industry, including aerial crop imaging, laser guided land-levelling, variable rate nitrogen application, and controlled traffic farming. In addition, most rice is sown by aircraft using satellite technology to guide seeding.

There is significant potential to increase rice productivity through decision agriculture, particularly through investing in areas that reduce in-crop variability (between high and low yielding areas). Intensive agriculture such as rice production favours variable rate management as poor performing areas in a high cost of production system can dramatically reduce farm profitability. Many paddocks have predictable yield zones associated with cut and fill maps, offering farmers the ability to develop a variable rate nutrition and soil conditioning program (Precision Agriculture, 2014). The yield of a typical rice crop can vary by 3–4t/ha, costing the Australian industry up to $150 Million per annum – variable rate fertiliser has proven its ability to close this yield gap between high and low yielding areas, delivering the potential to increase fertiliser efficiency by 10–15%.

Table A2.2: Opportunities to increase water use efficiency in the Australian rice industry.

There is significant potential for improved water use efficiency in the rice industry. A major breakthrough or 'step change' in water use efficiency could be delivered by the successful development of a high yielding rice production system that does not rely on water ponding i.e. aerobic rice production in the Riverina. Other potential productivity and water use efficiency improvements include: • The development of new varieties that have improved cold tolerance, a shorter growing season or produce a grain of higher unit value. • Opportunistic rice production system that takes account of late in the season water allocation. • Agronomic systems that maximise water productivity including greater uptake of delayed permanent water. • Understanding the causes of leaky soils that use uneconomic volumes of irrigation water including some areas of the Coleambally Irrigation Area. • Improvements in irrigation design/ layout including better irrigation scheduling, drainage management, and other findings from the current Smarter Irrigation for Profit project. • Utilising GIS systems to improve irrigation layout design. Regular laser levelling of paddocks ensures consistent water depth and is one of the most effective ways to improve water use efficiency and yield. • Managing soil sodicity with targeted gypsum applications based off yield maps and/or cut and fill maps can improve crop establishment and water quality. • Strategic GPS-referenced soil testing based off previous years' rice yield map and/or cut and fill map is important to monitor nutrient levels and soil health. • Improving compliance with strict environmental guidelines. • Sensors to monitor grain storage conditions and keep the rice at a suitable temperature and moisture level.

The potential economic benefits of decision agriculture for the rice industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the rice industry.

Other impacts* on the rice industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Market access and maintenance negotiation	Digital traceability and provenance systems providing confidence for end users in safety and quality of Australian rice. Impact: Maintaining and developing new high value markets for Australian rice.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Impact: Maintenance of markets and prevention of spread of pests.	*Connectivity:* Current connectivity status will be a barrier as real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. *Data/ Decision Support:* Not likely to be an impediment as relying on real time data. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Relatively small industry size and market for new technologies.
- Likely technology spillover from other cropping industries (i.e. few rice-specific technologies).
- Major role for processing sector (SunRice) to support the development and trial of new on-farm technologies.
- Water use efficiency is likely to continue being the single greatest driver of productivity and profitability. Technologies that assist decision-making (e.g. irrigation scheduling and crop stress monitoring) are likely to be in the greatest demand.

Table A2.3: The potential economic impacts of decision agriculture on the Australian rice industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Fallow weed control	Selective spraying based on either real time sensing technology (e.g. weedseeker) or application maps based on previous weed history. The assumption is that fallows are already weed free so there is no gain associated with increased soil water storage.	Reduction in intermediate inputs (chemical) of 15%	7.53	2.96
Irrigation planning, scheduling and application	Real-time sensed data on crop growth, combined with near and long term seasonal forecasting being analysed for better informed irrigation practice leading to increase in water use efficiency. Sensed data on water depth, flow and temperature etc combined with automation of application equipment leading to more precise application of water.	At the same time: • Yield increase of 15% & water costs reduced by 10%	38.93	14.59
Crop nutrition	Remote and proximal sensing technology for soil and plants in combination with aggregated and analysed multi farm data on nutrient status and yield provides recommendations for required nutrients for optimum yield. Variable rate application of fertiliser to minimise waste and optimise yield.	At the same time: • More and/or different fertiliser applied for greater yield and quality. 4% lift in output from increased spend on fertiliser. • The same amount of fertiliser applied but rate varied for optimum application rates. 4% lift in output. • Less fertiliser applied using more precise application for the same yield. 5% reduction in fertiliser costs.	11.85	18.89
In-crop weed and pest control	Targeted in crop control of weeds through remote or proximal sensing of weeds versus crop or map based spraying based on previous weed history. Targeted application of fungicides and pesticides directed by remote and proximal sensing combined with modelled and machine learned data.	Reduction in intermediate inputs (e.g. chemicals) of 10% [Use efficiency improvement]	2.05	0.80
Labour saving	Automation and robotics allows reduction in labour use. Electronic record keeping embedded in operations improve regulatory compliance (e.g. spray record keeping)	Labour costs reduced by 12%	17.81	8.45
		Total	**78**	**46**

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Fallow weed control	*Connectivity:* Current connectivity is largely sufficient to meet requirements. However, improvements will facilitate greater use of plant monitoring technologies (e.g. sensors) and data storage (i.e. cloud-based storage). *Data/ Decision Support:* Full utilisation is likely to be constrained by poor quality public data sets (e.g. soils and climate data). Challenges exist in layering and analysing multiple data sets. *Value Proposition:* Some technologies are commercially available. There is likely to be further international spill-over of technologies and business models. There are relatively low adoption rates of variable rate weed management but users are highly satisfied with results (i.e. further adoption is likely). *Legal/ Trust issues:* Concerns about data ownership and sharing (and power of large input suppliers) may limit full utilisation of benefits.
Irrigation planning, scheduling and application	*Connectivity:* Improvements in farm-wide connectivity will facilitate the uptake of remote/ proximal sensing technologies and automation of water management. *Data/ Decision Support:* Improvement to weather and climate forecasting is needed to unlock full potential of water management technologies. This could be achieved through better integrating public and private (e.g. farm) data sets and improving spatial resolution of forecasting. *Value Proposition:* Producers are heavily focused on improving water efficiency. Increased adoption of water saving technologies is likely to occur as cost-benefits become clear (e.g. reduced water costs and increased yields) *Legal/ Trust issues:* Not likely to have major impacts. Political pressure on tightening water regulation in the Murray-Darling Basin likely to have bigger impact on water use practices in the rice industry.
Crop nutrition	*Connectivity:* Improvements will facilitate greater use of plant monitoring technologies (e.g. sensors) and data storage (i.e. cloud-based storage). *Data/ Decision Support:* Full utilisation is likely to be constrained by poor quality public data sets (e.g. soils and climate data). Challenges exist in layering and analysing multiple data sets. *Value Proposition:* The value proposition for variable rate crop nutrition is well understood by producers. *Legal/ Trust issues:* Concerns about data ownership and sharing (and power of large input suppliers) may limit full utilisation of benefits.
In-crop weed and pest control	*Connectivity:* Improvements will facilitate greater use of plant monitoring technologies (e.g. sensors) and data storage (i.e. cloud-based storage). *Data/ Decision Support:* Full utilisation is likely to be constrained by poor quality public data sets (e.g. soils and climate data). Challenges exist in layering and analysing multiple data sets. *Value Proposition:* Value proposition needs to be demonstrated through a financial return (i.e. increased yield and/or quality, and reduced input costs). *Legal/ Trust issues:* Concerns about data ownership and sharing (and power of large input suppliers) may limit full utilisation of benefits.
Labour saving	*Connectivity:* Improved connectivity is essential for most in field labour saving technologies. *Data/ Decision Support:* Analysis of data is complex and time-consuming. Improved data management and new decision-support tools will help reduce farm labour requirements. *Value Proposition:* Adoption of labour saving technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Autonomous applications have legal and trust issues that are yet to be resolved. Does not necessarily require sharing of data throughout value chain.

Grains

Sector Overview

The grains industry, including oilseeds and pulses, is Australia's largest category of food exports. Production of grains is highly dependent on seasonal conditions. In a typical year, the annual farmgate value of production is $9 Billion, with 34 Million tonnes produced from an area sown to grains of around 20 Million hectares. In 2016–17, favourable seasonal and market conditions saw a significant increase in the volume and value of production (around $13.5 Billion).

The Australian grains industry has been a clear leader in terms of productivity gains among broadacre agricultural activities. Advances in cropping technology have supported industry wide productivity growth. At the farm level, more efficient farming systems, new crop varieties, digital technologies and conservation farming techniques have increased yields and sustainability while reducing costs (GrainGrowers, 2016).

Over the past five years, generally improved seasons, lower growth in costs and partial buffering from global price declines has improved the fortunes of Australian grain farm businesses. Consolidation and the resulting economies of scale have assisted in delivering productivity gains.

Despite more favourable rates of return during recent years, margins on grain production remain narrow, and increasing input costs continue to put pressure on farm profits and returns. On average, grain businesses have experienced an increase in their larger variable cost items including: fertiliser, oil and fuel, and chemicals (GrainGrowers, 2016). This trend stands despite the increasing size of these operations.

Production

Grain farming in Australia occurs across a diverse range of landscapes in three main regions: the northern, southern and western regions. Each has its own unique climatic, geographical, and management challenges.

Australia’s grains industry is national but varies by state and region in terms of crops grown and agronomic practices deployed. In any one year a grain farmer may grow a mix of wheat, coarse grains, oilseeds and pulses. The cropping program will be influenced by biophysical factors, market opportunities, including substitution to livestock production, and regulatory constraints.

The Australian grains industry is significant to the agricultural landscapes of New South Wales (NSW), Victoria, South Australia (SA), Western Australia (WA) and Queensland, and in some regions of Tasmania.

The Northern region

- Encompasses Queensland and northern New South Wales.
- Generally high soil fertility.
- High crop diversity (includes wheat, maize, sorghum, barley and oilseeds).
- Yield largely dependent on conserving soil moisture from summer rainfall.
- High-potential yields though with greater variability.
- Sugarcane, cotton and pastures can also be part of the farming system.
- Regional demand for livestock feed is a key production driver.

- It has relatively high seasonal rainfall and production variability compared with the other two regions. Both summer and winter crops are important for profit.
- The Northern Region is the largest source of Australia's premium hard high-protein wheat for export and domestic use.

Source: GRDC

The Southern region

- Includes Victoria, Tasmania, south-eastern South Australia, and central and southern New South Wales.
- Generally lower fertility soils, although there are some areas with very productive soils.
- Temperate climate.
- Yield largely dependent on autumn and spring rainfall.
- Varied crop production systems, including mixed farming enterprises.
- It has a diverse suite of soils of generally low fertility and with many subsoil constraints, such as salinity, sodicity and toxic levels of some elements, although there are also some areas with very productive soils.
- Yield potential depends on seasonal rainfall, especially in autumn and spring, and there is less dependence on stored soil moisture than in the Northern Region.

Source: GRDC

The Western region

- Comprises cropping areas of Western Australia.
- Mediterranean climate.
- Low yield, large-scale farming.
- Yield largely dependent on winter and spring rainfall.
- Dominant crops are wheat, barley, canola and lupins.
- Around 85 per cent of production is exported.
- In many areas, yields are low by world standards; this is compensated for by the large scale and degree of mechanisation of the enterprises.

Source: GRDC

Grain crops are grown in the 'cropping belt' of Australia, which comprises some 45 Million hectares (mha) (GRDC). This 'belt' starts in central Queensland and wraps itself inland down through NSW, Victoria, Tasmania and along the bottom edge of SA through the south-west to central WA. Newer, smaller, areas of grain production have been also been developing in northern WA, and northern QLD (GRDC).

There are a complex mix of factors that influence what a grain grower decides to sow in any given year. Biophysical factors, largely soil and climate, of any given location will guide a basic set of crop options and be the major components of the decision, followed by expected price (GrainGrowers, 2016).

Other elements that guide crop selection include expected rainfall and its timing, crop rotational considerations related to pests, weeds and disease, and soil conditions, local markets, receival site options, prevailing livestock prices and risk management.

Australian grain production is dominated by winter crops, sown between March and June depending on geographical location and the timing of rainfall. Winter production is supplemented by summer grain production across Queensland and northern, and increasingly more widely into southern NSW. Most cropping regions across Australia can only produce one crop per year, but some areas can produce both a summer and winter crop each year due to favourable soil types and climate.

The industry's main outputs — wheat, barley, canola, sorghum, oats and a range of pulses — together consistently account for more than 25% of the value of Australian agricultural production and an even greater proportion of Australian agricultural exports (averaging 30% during 2010–15) (GrainGrowers, 2016). The grains industry also contributes to a further 40% of the value of Australian agriculture through the provision of feed grain rations to the intensive livestock sectors (primarily cattle, poultry, pigs and dairy) (GrainGrowers, 2016).

Wheat is the mainstay of the Australian grains industry (accounting for 56% of total grain tonnes produced), followed by barley (18%), canola (8%), sorghum (4%), oats (3%) and a range of pulses (collectively 5%) (GrainGrowers, 2016).

This proportionate share between the different crops is typical of Australian grain production over the long-term, although the relative proportion of canola and pulses has increased more recently

The Australian grains industry relies on multiple grain crops and within each grain type, multiple varieties. The capacity to substitute grain crops and varieties is fundamental to managing risk in grain-growing businesses and supporting the capacity to respond to increased exposure to global market dynamics that comes with an internationally exposed industry. The development of new and improved varieties is critical to the industry's long-term success. Technologies such as GM have the potential to deliver new high-performing varieties with particular traits such as increased drought resistance.

Supply Chain Logistics

The Australian grains industry comprises a sophisticated supply chain, which includes input suppliers, traders, bulk handlers, port operators, processors and other allied service providers. The industry collectively accounts for more than 170,000 jobs across Australia from farm to export dock (GrainGrowers, 2016).

Getting up to 45mt of grain to market each year is a substantial task, engaging a network of rail and road freight, on-farm and regional up-country storages and metropolitan and port storages (GrainGrowers, 2016). More than 60% of Australian grain is exported and many domestic milling and processing facilities are concentrated in coastal metropolitan areas, so the movement of grain from farm, to country storages and to the coast is a dominant feature of the entire Australian grain supply chain.

For the most part, and certainly for wheat and barley, the movement of grain in Australia is characterised by peak-load movement during harvest and the following two to three months. This is in contrast to the systems in some competitor nations (e.g. Canada) where there is more on-farm storage and the movement of grain to port occurs over extended periods.

This Australian system is based around delivery of grain into a bulk handling system operated by regional monopolies and characterised by a small number of segregations for each grain type at each delivery point and co-mingling of farmer deliveries, to a stack average based on receival standards (GrainGrowers, 2016). Grain accumulators, either independent marketing companies or marketing arms of the bulk handlers, or growers, can maintain ownership of their grain throughout the bulk handling system based on adherence of the system to the receival standards. Storage and handling of grain in Australia is currently dominated by four regional players, GrainCorp, CBH, Viterra and Cargill’s Grainflow, and characterised by increasing international ownership.

Australia's grain freight network is less efficient than many of its major competitors. The inefficiency of Australian rail infrastructure leads to a reliance on road transport for grain. Australian grain trains are run on low-efficiency lines with 16–19t axle loads carrying 2000–3000 net tonnes of grain per train compared with Canadian trains of 23t axle loads carrying 11,000t of grain (AEGIC, 2015). This inefficiency is demonstrated by a comparison of the average per kilometre per tonne grain movement. The cost for grain movement in Canada is $0.03 compared with $0.11 in Australia.

The level of on-farm grain storage has increased in recent years. This has been driven by a desire by growers to expand their marketing options, cater to different freight modes and adjust to seasonal variability. It also includes catering to the domestic market, which is characterised by a greater proportion of direct sales with delivery direct to the end-user.

Exports

Australia’s grains industry is predominantly export focused. The industry’s largest production crop, wheat, is also the most highly export dependent. Typically, 75% of wheat production is exported. Other Australian grains are less export-dependent than wheat. Typically, about 50% of sorghum is exported, 65% of barley and just 17% of oats.

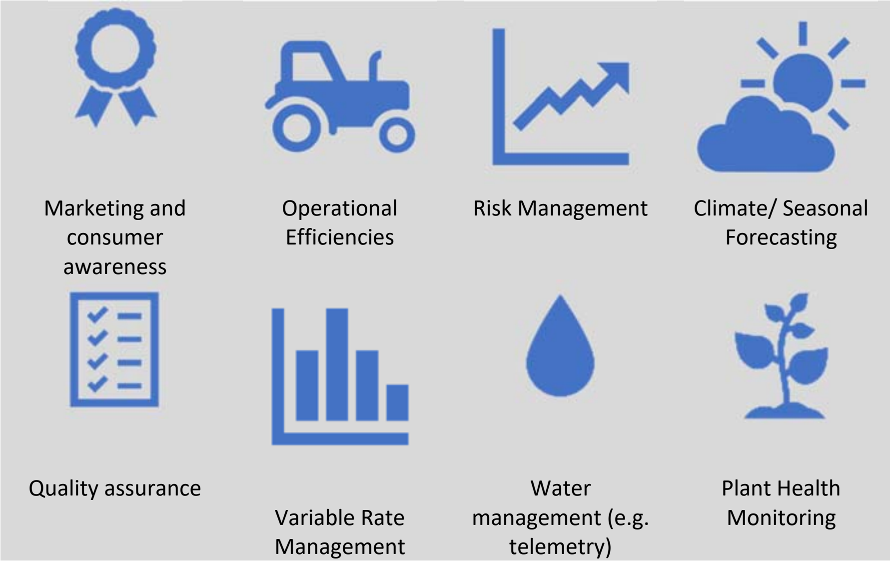
This means about 60% of the volume of grains produced in Australia is exported. This balance varies by state across Australia, with WA being the most export-dependent state. Wheat, for example, accounts for 70% of WA’s cereal production, and more than 80% of wheat grown in WA is exported. Meanwhile, the east-coast states are significantly less export dependent due to the more readily-accessible domestic end-use markets.

Australia produces just 3–4% of annual international wheat production. However, accounting for 10–15% of global wheat exports, with variability dependent on domestic supply, Australia is an important player in the global wheat trade (GrainGrowers, 2016).

Australia produces 5% of annual international barley production, but is the world's largest exporter of barley (accounting for more than 30% of the malting barley trade and 20% of the global feed barley trade) (GrainGrowers, 2016).

As a largely export-orientated industry (around 60% of grain is exported each year), exchange rates have a major effect on the profitability of the Australian grains industry. In recent years, a depreciation of the Australian dollar ($AUD) to the US dollar has improved the international competitiveness of Australian grain exports. However, at the same time, depreciation has also increased the cost of the inputs such as fuel, fertiliser and chemicals, as well as capital items, such as tractors and headers.

Key Drivers of Decision Agriculture



There are a complex range of physical (e.g. water availability, climate, soil quality) and management factors that influence the profitability of grain production. A recent report by the GRDC (2016) identified the following key profit drivers in the Australian grains industry:

- Crop choice – growing the most profitable crop
- Planting decisions – timing/ soil moisture
- Crop rotations
- Maximising soil moisture
- Varietal selection
- Fertiliser management
- Optimising water use
- Good results from planting and other farm operations (including harvesting)
- Timeliness
- Weed control
- Good labour management
- Risk management

Climate variability has a major impact on production and a GrainGrowers' decision making. In any given season, a farmer can choose not to plant a crop — thereby negating the risk of wasted inputs costs (seed, fertiliser, fuel, herbicides, labour) if the crops fails due to unseasonal climate events but also foregoing the opportunity for return on assets from a crop produced (GrainGrowers, 2016). As climate variability increases, the value and requirement for information to reduce uncertainty grows. In the absence of accurate climate information, the opportunity costs of not growing a crop, or the direct losses of input costs, will also grow. In other words, there is a fundamental need and huge demand for decision agriculture in the grains industry.

The potential economic benefits of decision agriculture for the grains industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the grains industry.

Other impacts* on the grains industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Market access and maintenance negotiation	Digital traceability and provenance systems providing confidence for end users in safety of grain. Maintaining and developing new high value markets for Australian grain.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Maintenance of markets and prevention of spread of pests.	*Connectivity:* Current connectivity status will be a barrier as real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. *Data/ Decision Support:* Not likely to be an impediment as relying on real time data. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Large market for new technologies (likely to attract new business models).
- Likely direct spillover of products and services (and business models) from North America, including off-the-shelf/ 'Plug-and-Play' technologies.
- High historical adoption of precision agriculture sets precedent for decision agriculture.
- Need for international technologies to be tested and adjusted to suit Australian conditions (e.g. different climate & agronomic factors) and Australian constraints (e.g. low internet connectivity).

Table A2.4: The potential economic impacts of decision agriculture on the grains industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Fallow preparation	Selective spraying based on either real-time sensing technology (e.g. weedseeker) or application maps based on previous weed history.	Chemical use reduced by 15%	343.4	108.4
Crop rotation	Soil water sensing combined with seasonal forecasting analytics and impacts of previous crops etc giving more certainty to the most profitable crop rotation decisions and overall farming system planning.	Overall productivity increased by 5%	1756.0	532.5
Planting	Beyond NVT – varieties matched to soil type and geography for maximum yield and quality. Information on varietal performance derived from yield data from multi farm accumulated data (see FBN case study). Most appropriate varieties planted to suit pest status of planting location (nematode and other soil borne pathogen risk, rust risk etc) informed by real time data on pest status. Variable rate seeding to plant optimum rate according to soil type, soil water status, and other environmental factors. Rate determined by combination of real time sensed data (soil water status etc) and modelling/machine learned analysis of optimum rate for planting location. Time of sowing maximised for optimum yield informed by sensing of soil water conditions combined with medium and long-term weather analytics.	Increase in yield of 10% (Equates to overall productivity increase of 3.28%)	1152.2	349.1

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Fallow preparation	*Connectivity:* Current connectivity is largely sufficient to meet requirements. However, improvements will facilitate greater use of plant monitoring technologies (e.g. sensors) and data storage (i.e. cloud-based storage). *Data/ Decision Support:* Much of the technology associated with fallow preparation is real time and does not require integration with data and data analytics. Not a significant constraint. *Value Proposition:* Some technologies are commercially available. There is likely to be further international spill-over of technologies and business models. There are relatively low adoption rates of variable rate weed management but users are highly satisfied with results (i.e. further adoption is likely). *Legal/ Trust issues:* Large amounts of data sharing not required. Not likely to be a significant constraint.
Crop rotation	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils and weather information. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Potential to induce fundamental changes in cropping systems and rotations. Very large value proposition but will need buy in from growers to accept need for change. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Planting	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information and machine control. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Planting the right crop at the right time in the right place with the right rate is critical for maximising yield potential. Value proposition for getting this correct is significant. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Crop nutrition	Remote and proximal sensing technology for soil and plants in combination with aggregated and analysed multi farm data on nutrient status and yield provides recommendations for required nutrients for optimum yield. Variable rate application of fertiliser to minimise waste and optimise yield.	At the same time: • More and/or different fertiliser applied for greater yield and quality. 2% lift in output from increased spend on fertiliser. • The same amount of fertiliser applied but rate varied for optimum application rates. 2% lift in output with fixed fertiliser cost and efficiency gain spread across other inputs. Less fertiliser applied using more precise application for the same yield. 5% reduction in fertiliser costs.	1000.1	223.9
Crop protection and weed control	Targeted application of fungicides and pesticides directed by remote and proximal sensing combined with modelled and machine learned data. Targeted in-crop control of weeds through remote or proximal sensing of weeds versus crop or map based spraying based on previous weed history.	Chemical use reduced by 4%	91.0	28.9
Labour saving	Automation and robotics allows reduction in labour use. Electronic record keeping embedded in operations improves compliance.	Labour costs reduced by 12%	878.0	367.0
Yield Forecasting	More accurate yield forecasting using remote sensed data allows for higher confidence levels in marketing programs. Higher prices achieved through taking advantage of market opportunities.	Overall productivity increased by 2%	702.8	212.9
		Total	**5930**	**1823**

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Crop nutrition	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information and machine control. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets, particularly more granular soils information which is currently lacking. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Inappropriate nutrient application is one of the most common management induced yield constraints. Value proposition for appropriate nutrient application to maximise productivity and profitability is significant. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Crop protection and weed control	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information, plant sensing and machine control. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets and imagery. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Weeds and disease are significant drags on yield. Significant value proposition for technology which leads to more effective control. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Labour saving	*Connectivity:* Improved connectivity is essential for most in field labour saving technologies. *Data/ Decision Support:* Analysis of data is complex and time-consuming. Improved data management and new decision-support tools will help reduce farm labour requirements. *Value Proposition:* Adoption of labour saving technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Autonomous applications have legal and trust issues that are yet to be resolved. Does not necessarily require sharing of data throughout value chain.
Yield Forecasting	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils and weather information. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets, particularly more granular soils information which is currently lacking. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* More confident forecasting of yield will enable different marketing strategies and have potentially significant financial implications. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.

Cotton

Sector Overview

Cotton is often touted as one of Australian agriculture's greatest success stories. The modern cotton industry emerged in the 1960s, driven by US investors, and has evolved into the world's leading cotton industry – by yield, quality and water efficiency. Key factors underpinning the industry's success are a culture of innovation and a high level of adoption of best management practices. Digital technologies have the potential to further transform the highly productive cotton industry.

Australia remains a small cotton producer by global standards, but due to its cost competitiveness, high yields, and premium quality product, has a significant share of the world's high/ medium grade cotton trade. Australian cotton is recognized for its high quality, including low foreign-matter contamination and long staple (fibre) length. Australia's major markets for cotton include China, Indonesia, Thailand and Korea.

The recent success of the Australian cotton industry can be partly attributed to advances in biotechnology and the adoption of GM cotton varieties. The impetus for adopting insecticidal GM technology was the speed with which the pest *Helicoverpa armigera* (cotton bollworm) had developed resistance to insecticides.

Advances in farm equipment and quick adoption of new technologies have helped the industry reduce production and harvesting costs. In recent years, round-module pickers have been widely adopted. The cost of these pickers is very high, but they significantly reduce labour requirements. Instead of employing labour-intensive separate operations, the new machines combine the picking, module building and wrapping processes. There have also been technological advances in cotton ginning with real time monitoring used to manage moisture during ginning, which has helped to reduce cotton fibre damage.

Cotton Production

Cotton is grown in Australia by around 900 cotton growers on 1250 farms in QLD and NSW. There are some commercial trials occurring in Victoria (VIC). According to Cotton Australia the average Australian cotton farm:

- is family owned and operated.
- directly creates jobs for 6–7 people.
- is run by growers with an average age of 39.
- grows 495 hectares of cotton, comprising 17% of the total farm area.
- supplements cotton with other crops including wheat, chickpeas and sorghum, and many Australian cotton farmers also graze sheep and cattle.
- dedicates 42% of farm area to native vegetation.

Farms are relatively large and labour intensive (seasonally). A number of large corporate businesses own cotton farms and there is some vertical integration between the production and processing sectors.

The map below illustrates the location of major cotton growing regions. The major production area in NSW stretches south from the Macintyre River on the Queensland border and covers the Gwydir, Namoi and Macquarie valleys. In NSW cotton is also grown along the Barwon and Darling rivers in the west and the Lachlan and Murrumbidgee rivers in the south. Production is influenced by a range of factors, including the availability of water (level of water entitlements received each year).

In Queensland, cotton is grown mostly in the south in the Darling Downs, St George, Dirranbandi and Macintyre Valley regions and the remainder is grown near Emerald, Theodore and Biloela in Central Queensland. Cotton has also been trialled in northern Victoria in recent years.

Expansion in northern cropping regions is possible given warm growing conditions. There is scope for large tracts of land to be transferred from summer cereal cropping to cotton production. However, there are currently few gins operating, meaning the costs of transport in some regions are very high. In contrast, new gins have opened in southern NSW which has encouraged further production. However, production in southern growing regions is constrained by temperature.

Figure A2.1 A map of Australia's cotton growing regions.

Source: Cotton Australia.

In the northern growing regions, where rainfall is summer dominant, higher temperatures allow growers to plant and harvest much earlier and later than the central valleys. The cotton growing season typically runs from August/ September to February/ March or from November/ December to May/June.

In the central NSW growing regions the season typically runs from October/ November to April/ May. Mainly summer dominant rainfall to non-seasonal rainfall in the more southern areas.

In the southern regions, where rainfall is winter dominant, a longer season is required to allow cotton to develop and grow due to cooler temperatures. The season typically runs from October to May.

Cotton Ginning

Cotton ginning involves the separation of cotton fibres (lint) and cottonseed. There are a growing number of cotton gins operating in Australia including:

- Auscott Limited
- Brighann Ginning
- Carroll Cotton Company
- Cubbie Ginning Pty Ltd
- Namoi Cotton Co-op
- North West Ginning Pty Ltd
- Queensland Cotton Corporation Pty Ltd (owned by Olam)
- RivCott
- Southern Cotton
- Wathagar Ginning Company

Cotton Exports and Consumption

Australia is the world's fourth-largest cotton exporter and seventh-largest producer behind China, India, the USA, Pakistan, Brazil and Uzbekistan. On a global scale, demand for fibre is growing and cotton is the number one natural fibre. Alternative, synthetic fibres are made from refined oils.

On a global scale, Australia is not a large cotton producer – only around three per cent of the global crop is grown within Australia. The five-year average production quantity from 2009–2014 is 3.9 Million bales (approx. 885,300 metric tonnes) (Savage, 2016).

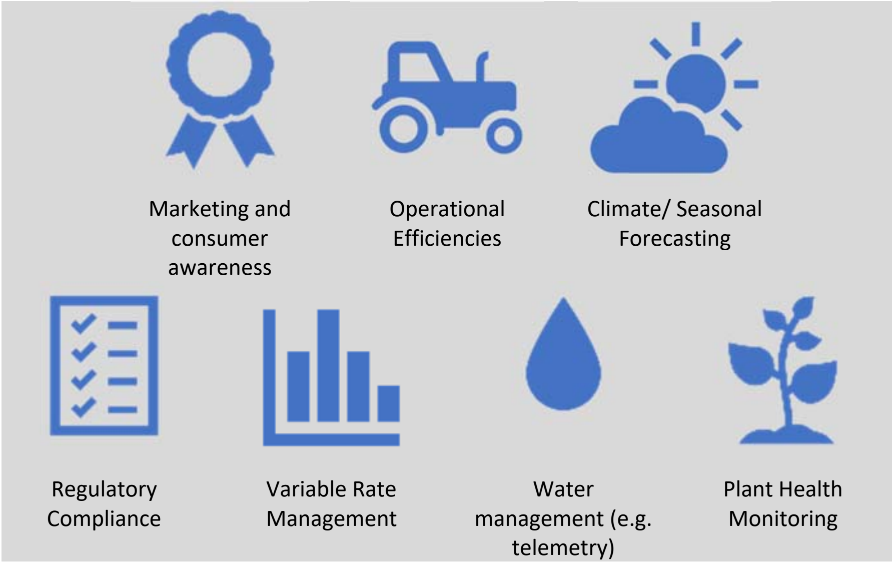
Price volatility reflects Australia’s small position in the global cotton trade. Many growers use international cotton futures markets (i.e. Chicago Mercantile Exchange – CME) to manage price volatility.

Over the past five years the industry has generated an average of $1.9 Billion in export revenue per annum. Australia produces around 3% of the world’s cotton but is the third largest exporter, behind the US and India. The major buyers of Australian cotton are currently China (68%), Indonesia, Thailand, South Korea, Bangladesh and Japan (CRDC and Cotton Australia, 2014).

Other products

The farmgate value of cottonseed production is around $200 Million. Cottonseed is commonly used as a stockfeed or crushed for use as a cooking oil.

Key Drivers of Decision Agriculture



Digital agriculture has already led to significant improvements in the productivity and profitability of the Australian cotton industry. In the next ten years there are likely to be further gains. There are four key areas where these gains are likely to occur:

- **Planning**
  - Seasonal Forecasting
  - Water supply planning
  - Varietal choice
  - Field selection and preparation
  - Area planted
  - Labour use and OH&S
- **In-Season Management**
  - Fertiliser and soil management
  - Pest management
  - Irrigation management
  - Crop establishment
  - Crop growth
  - Managing fibre quality
- **Harvest and Post-Harvest**
  - Preparing for harvest
  - Harvesting
  - Managing stubbles/ residues
  - Ginning and classing
- **Marketing and Value Chain**
  - Cotton marketing and traceability
  - Supply chain logistics
  - Finance, insurance and risk management

The theoretical yield potential of Australian cotton has been estimated at around 22 bales/ ha (Constable and Bange, 2015). The current industry average (2014–15) for irrigated cotton is 11.5 bales/ ha and 4 bales/ ha for rainfed cotton (CRDC, 2016). Experts estimated that a figure of around 80% of this theoretical yield should be considered a realistic attainable yield, given resource/economic constraints and an appropriate level of risk-reward. As part of the P2D project the following industry targets were identified:

- 13–16 bales/ha industry average for irrigated cotton (i.e. overall 20–40% increase)
- 6–8 bales/ha industry average for dryland cotton (i.e. overall 50–100% increase).

Planning

Seasonal Forecasting – Water is the single biggest limiting factor affecting cotton production. Accurate forecasting of water supply and demand, including weather forecasting and real-time crop demand has the potential to have major impacts on cotton yields. Improved forecasting at Basin, catchment, local and farm scales over a range of time periods (short, medium and long-term) would give growers greater confidence to make major investment decisions such as those around planting area and irrigation scheduling.

Water supply planning – The industry has made huge improvements in water use efficiency (increased W.U.E. by 40% in the 2000s). There is potential to further increase water use efficiency through technologies that allow real-time monitoring and automation (e.g. sensors).

Varietal choice – The analysis of big data sets (including soil, topography, yield, and historical land use) could enable better decision-making at planting about cotton varietal choice. For example, it could allow growers to benchmark or forecast production potential for certain varieties by region or soil type.

Field selection and preparation – There are a range of factors affecting the variation of yields achieved within and between paddocks. Big data analytics could assist growers make decisions about field configuration, location, orientation and varietal choice.

Area planted – There is likely to be further expansion in the area planted to cotton over the next ten years. The most significant factor is likely to be the relative profitability of alternative land uses, particularly sorghum. Increasing the productivity of cotton while also reducing production risks (variability) will increase cotton's competitiveness with sorghum. Digital technologies will be an important factor influencing the expansion of cotton production. There is huge agronomic potential for cotton. A 2014 study by EcoLogical Australia, commissioned by CRDC, estimated that it is feasible that cotton be grown on up to 1m ha. In the past decade up to 600,000ha of cotton has been planted. It is likely that rainfed cotton will account for most of the expansion in plantings (CRDC and Cotton Australia, 2014).

Labour use and OH&S. – Digital technologies have the potential to reduce and reallocate farm labour. The use of networks of real-time sensors could potentially double labour efficiency by allowing labour-intensive jobs, such as monitoring irrigation, to be automated. There are going to be costs involved in up-skilling workers to meet the requirements of new technologies. These costs include technical and Operational Health & Safety (OH&S) training. The role of agronomists and farm service providers is likely to change significantly.

In-Season Management

Fertiliser and soil management – Nitrogen use efficiency could be significantly be improved by 25% over the next ten years. The availability of nitrogen sensors could be used to facilitate the variable rate application of nitrogen (and other nutrient deficiencies). These sensors would provide real-time information on crop nutrient status and plant development. There is still a need for better modelling of nitrogen uptake at the plant level.

Pest and disease management – The management of pests and diseases is a major factor affecting the costs and yields of cotton production. The development of technologies like GM have directly impacted the management of pests and diseases. The costs of using GM technologies (e.g. Monsanto's technology fee) are significant. Using GM varieties has drastically cut the volume of pesticide use. However, the overall cost of pest management has remained roughly the same when the technology fee is considered.

While the impact of bollworms has been largely mitigated by cotton varieties, there are a number of issues that remain. This includes herbicide resistance of weeds. Pests and diseases that affect cotton at the end of season including white fly and aphids have a significant impact on cotton quality. New technologies that help with the detection and management of pests and diseases (including site specific management tools, sensors, and swarm farm robotics) could potentially reduce the cost of insecticide use by $50/ha.

Irrigation management – Full implementation of decision agriculture could reduce water use by 10–20%. Savings could be achieved by:

- Reduced evaporation of water
- Savings in pumping and delivery costs (e.g. bore costs)
- Improved timing of watering (too much or not enough water) based on real-time crop water demand.

Crop establishment – One of the biggest factors affecting yields is the timing of planting. Improved decision-making at planting time could reduce crop losses and improve yields.

Crop growth – Increased monitoring of real-time crop growth and plant stress can support early intervention (e.g. herbicide spraying, fertilising or watering) that would improve crop growth and yield.

Managing fibre quality – Improved monitoring of plant stress and soil moisture can allow growers to make management decisions that protect and improve fibre quality. For example, the timing of watering to help balance between plant vegetative size and uniform boll setting pattern.

Harvest and Post-Harvest

Preparing for harvest – The timing of harvest can have a significant impact on yield and cotton quality. The main quality factors affecting cotton pricing are fibre length, strength, colour and consistency. Better harvest preparation could help reduce harvest discounts by 5–10%.

Harvesting – A lot of new machinery and equipment is fitted with the capacity for preventative diagnostics/ maintenance. These technologies could reduce input use (e.g. fuel reductions by 5%)

In the longer-term it is likely that there will be new developments in harvesting technologies, including driverless tractors and round-bale module pickers.

Managing stubbles/ residues – Managing stubbles and crop residues can improve water efficiency, improve soil health, and reduce the incidence of pests and diseases for the next growing season.

Ginning and classing – The value of cottonseed industry is worth around $200m p.a. This value has traditionally covered the costs of ginning cotton (to produce the higher value product cotton lint). In the future, it is possible that a range of new products are developed to add value to cottonseeds. Increased popularity of cottonseed oil could have a major impact on the bottom line of producers and processors. However, it is unlikely in the next ten years that any new major product or market developments will dramatically transform the value of cottonseed.

Marketing and Value Chain

Cotton marketing and traceability – 'More complete' data across the supply chain (from farm to retail) has potential to increase the marketability of cotton and maintain market access. For example, it could allow Australian cotton to market its sustainability credentials.

Supply chain logistics – It is estimated that supply chain efficiencies including transport and logistics could potentially reduce these costs by around 25%. Reducing the cost-price of cotton and improving its consistency (quality etc…) would increase its competitiveness at a processing level against synthetic fibres.

Finance, Insurance and risk management – Cotton production is highly capital-intensive. Improved decision agriculture technologies, particularly seasonal forecasting, could help businesses to more effectively manage their working capital. It could also help businesses attract new capital. It is difficult to quantify how big data will reduce the cost of capital. However, it appears like that digital technologies will lead to reductions in transaction costs across the supply chain. Technologies like 'Block Chain' are being keenly watched for their ability to save money, people and time. It is possible that transaction costs could be reduced by 2–3% by these technologies.

The potential economic benefits of decision agriculture for the cotton industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the cotton industry.

Other impacts* on the cotton industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Market access and maintenance negotiation	Digital traceability and provenance systems providing confidence for end users in quality of Australian cotton. Maintaining and developing new high value markets for Australian cotton.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Maintenance of markets and prevention of spread of pests.	*Connectivity:* Current connectivity status will be a barrier as real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. *Data/ Decision Support:* Not likely to be an impediment as relying on real-time data. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Moderately sized industry.
- Australian sector is regarded as global leader in digital agriculture.
- Likely international spillover from other broadacre cropping industries.
- Likely pull-through from large global retail market (e.g. fashion industry and consumer goods).
- High historical adoption of precision agriculture sets precedent for decision agriculture.
- Highly capable and digitally mature user base (generally large, capital-intensive businesses with high existing adoption of precision agriculture).

Table A2.5: The potential economic impacts of decision agriculture on the Australian cotton industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Crop nutrition	Remote and proximal sensing technology for soil and plants in combination with aggregated and analysed multi farm data on nutrient status and yield provides recommendations for required nutrients for optimum yield. Variable rate application of fertiliser to minimise waste and optimise yield.	At the same time: • More and/or different fertiliser applied for greater yield and quality. 4% lift in output from increased spend on fertiliser. • The same amount of fertiliser applied but rate varied for optimum application rates. 4% lift in output with fixed fertiliser cost and efficiency gain spread across other inputs. • Less fertiliser applied using more precise application for the same yield. 5% reduction in fertiliser costs.	99.3	83.0
Crop protection and weed control	Targeted application of fungicides and pesticides directed by remote and proximal sensing combined with modelled and machine learned data. Targeted in-crop control of weeds through remote or proximal sensing of weeds versus crop or map based spraying based on previous weed history	Chemical use efficiency increases by 10%	13.4	24.9
Operational efficiencies	Reduction in fuel use	Fuel use reduced by 5%	7.2	11.8
Irrigation planning, scheduling and application	Real time sensed data on crop growth, combined with near and long term seasonal forecasting being analysed for better informed irrigation practice leading to increase in water use efficiency. Sensed data on water depth, flow and temperature etc combined with automation of application equipment leading to more precise application of water.	Overall productivity increased by 15%	144.8	303.4

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Crop nutrition	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information and machine control. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets, particularly more granular soils information which is currently lacking. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Inappropriate nutrient application is one of the most common management induced yield constraints. Value proposition for appropriate nutrient application to maximise productivity and profitability is significant. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Crop protection and weed control	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information, plant sensing and machine control. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets and imagery. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Weeds and disease are significant drags on yield. Significant value proposition for technology which leads to more effective control. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Operational efficiencies	*Connectivity:* Improved connectivity is essential for most in field efficiency improvement technology. *Data/ Decision Support:* Not a significant barrier as most efficiency improving technology will rely on real-time information. *Value Proposition:* Adoption of fuel saving technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Not perceived to be a significant constraint.
Irrigation planning, scheduling and application	*Connectivity:* Improvements in farm-wide connectivity will facilitate the uptake of remote/ proximal sensing technologies and automation of water management. *Data/ Decision Support:* Improvement to weather and climate forecasting is needed to unlock full potential of water management technologies. This could be achieved through better integrating public and private (e.g. farm) data sets and improving spatial resolution of forecasting. *Value Proposition:* Producers are heavily focused on improving water efficiency. Increased adoption of water saving technologies is likely to occur as cost-benefits become clear (e.g. reduced water costs and increased yields) *Legal/ Trust issues:* Not likely to have major impacts. Political pressure on tightening water regulation in the Murray-Darling Basin likely to have bigger impact on water use practices in the cotton industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Labour savings	Automation and robotics allows reduction in labour use. Electronic record keeping embedded in operations improves compliance	Labour costs reduced by 12%	33.1	73.2
Improved fibre quality	Price premium due to improved fibre quality	Overall productivity improvement 6%	87.7	178.7
Improved marketing	Reduction in selling/ transaction costs	Productivity improvement in margins 2%	2.1	4.2
Reduction in supply chain costs	Improved supplied chain efficiencies, logistics and transport	Productivity improvement of transport by 2%	6.9	12.9
		Total	**394.5**	**692.1**

Source: AFI and CRDC 2017.

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Labour savings	*Connectivity:* Improved connectivity is essential for most in field labour saving technologies. *Data/ Decision Support:* Analysis of data is complex and time-consuming. Improved data management and new decision-support tools will help reduce farm labour requirements. *Value Proposition:* Adoption of labour saving technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Autonomous applications have legal and trust issues that are yet to be resolved. Does not necessarily require sharing of data throughout value chain.
Improved fibre quality	*Connectivity:* Mostly affecting post fieldwork activity so connectivity not likely to be a barrier. *Data/ Decision Support:* Will require integration of data and datasets. Potential constraint. *Value Proposition:* Quality payments are significant component of profitability. Value proposition significant for boosting quality. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Improved marketing	*Connectivity:* Mostly affecting post fieldwork activity so connectivity not likely to be a barrier. *Data/ Decision Support:* Will require integration of data and datasets. Potential constraint. *Value Proposition:* Adoption of efficiency boosting technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Reduction in supply chain costs	*Connectivity:* Improved connectivity is essential for most in field efficiency improvement technology. *Data/ Decision Support:* Not a significant barrier as most efficiency improving technology will rely on real time information. *Value Proposition:* Adoption of efficiency boosting technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Not perceived to be a significant constraint.

Sugar

Sector Overview

The Australian sugarcane industry is located mainly along Australia's eastern coastline, from Mossman in far north Queensland to Grafton in northern New South Wales. There are approximately 4400 cane farming entities growing sugar cane, supplying 24 mills, owned by 8 separate milling companies (Australian Sugar Milling Council website).

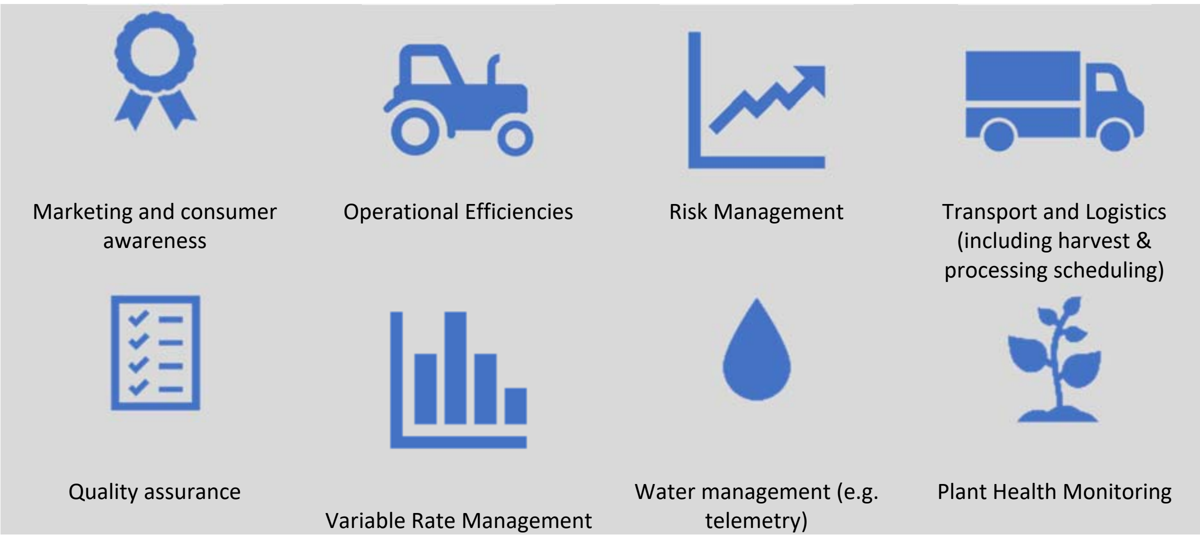
Milling companies are a combination of publicly owned entities, privately held companies limited by guarantee, and co-operatives.

The industry's major product is raw crystal sugar, which is sold to refineries both domestically and abroad. Approximately 95% of Australian sugar produced comes from Queensland with the balance from northern New South Wales.

Up to 35 Million tonnes of sugarcane is grown on about 380,000 hectares annually. The Australian sugar industry can produce up to 4.5 Million tonnes of raw sugar, 1 Million tonnes of molasses and 10 Million tonnes of bagasse annually (Australian Sugar Milling Council website). Approximately 85% of the raw sugar produced in Queensland is exported, generating up to $2.0 Billion in export earnings for Queensland (Australian Sugar Milling Council website). Production from the New South Wales sugar industry is refined and sold into the domestic market.

The Australian sugar cane industry has undergone significant rationalisation in the production and processing sectors over the past decade with the closure of several mills as well as a departure of growers from the industry and subsequent amalgamation of farming and harvesting operations. This rationalisation has already seen some changes in terms of mill ownership and structures to promote greater cohesion and efficiency of operations, with an expectation that this could continue. The sugar industry directly employs about 16,000 people across the growing, harvesting, milling and transport sector (Australian Sugar Milling Council website).

Key Drivers of Decision Agriculture



The uptake of precision agriculture in the Australian sugar industry has lagged behind many other agricultural industries, however there has been a high level of adoption of GPS guidance for machinery. There are several reasons for this including the unique growing and harvesting processes involved in the sugar industry. The long growing season of sugarcane, combined with a limited period where inputs can be applied, can make it difficult to implement precise and variable application of inputs. Other factors affecting the adoption of precision agricultural practices include grower risk aversion, farm size versus technology cost, lack of cost-benefit data, and lifestyle preferences that coincide with precision agriculture management needs.

Maintaining the industry's social licence to operate

Arguably the greatest challenge facing the Australian sugar industry as a whole is managing community expectations and government regulatory requirements related to the environmental impact of production. There is a particular focus on the impacts of chemicals and nutrient run-off on the Great Barrier Reef.

Remote Sensing

There is strong interest in the potential of remote sensing technologies in the sugar industry. Remote sensing allows information about an object to be collected without the requirement for physical contact with the object. This could be particularly useful in a crop like sugarcane, because physical access is made difficult once the plant reaches a certain size. Remote sensing could be used to help identify spatial variability e.g. in water availability, soil nutrient status, and crop quality. For example, remote sensing imagery of the spectral reflectance characteristics of the canopy could be used to identify under-performing parts of paddocks and guide targeted agronomy. Potential benefits of remote sensing in sugarcane include (Sugar Research Australia 2015):

- Producing farm-level and block level yield maps
- Forecasting regional yields and assisting to assist with sugarcane harvesting and milling schedules
- Evaluating the effectiveness of irrigation
- Identifying and managing canegrubs
- Monitoring Yellow Canopy Syndrome (YCS)

Yield and quality monitoring

Accurate and timely prediction of sugarcane yield and quality has the potential to deliver several benefits which would improve the efficiency and profitability of the Australia sugar industry. This includes supporting decision-making processes such as crop harvesting scheduling, marketing, milling and forward selling strategies. Currently, the in-season estimation of yield is undertaken using visual or destructive sampling techniques by either growers or mill funded productivity officers (Rahman and Robson, 2016). However, this method is labour intensive with accuracies influenced by varied seasonal climatic conditions and crop age due to an extended harvest period and human error (Rahman and Robson, 2016).

There is generally limited use of harvester mounted yield monitoring devices. These offer varied degrees of yield mapping accuracy, but data is only available post-harvest and therefore not available to support in-season decision making (Rahman and Robson, 2016). Remote sensing technologies have the potential to provide an alternative method of accurately and cost-effectively predicting sugarcane yield.

Australian researchers, led by the University of New England, have developed satellite monitoring techniques to accurately estimate sugarcane crop growth and forecast yield. The technique involves developing a green normalized difference vegetation index (NDVI) to determine crop phenology, biomass, and productivity in spatial resolution. Sequential observations of GNDVI can provide seasonal crop profiles that show the progression of crop canopy from emergence to senescence. These profiles reflect the crop performance based on environmental factors and are related to the final crop yields. (Rahman and Robson, 2016).

Time series satellite observations provide an accurate indication of crop response over time, whether it be the result of environmental changes occurring from rainfall distribution, drought, nutrient deficiency and other related factors or different human management practices such as fertiliser application, pests, weeds and diseases control etc (Rahman and Robson, 2016).

The development of a commercial cane sugar sensor (CCS) would open up major opportunities to improve the productivity and profitability of the sugar industry. Currently, there is no way to reliably measure sugarcane quality in the field (Rahman and Robson, 2016). The development of a CCS would open up major opportunities to improve the productivity and profitability of the sugar industry. This includes helping scheduling harvests to optimise sugar value (Sugar Research Australia, 2016). It would also allow production inputs to be optimised. Such a sensor would allow a greater understanding of causation and correlation between yield and quality. As Sugar Research Australia (2016) put it: *"research has not been able to establish a link between yield and CCS, but many precision agriculture activities focus on optimising yield without understanding potential impacts on CCS."*

Harvest losses are a major cost to sugarcane businesses. It is estimated that around 10% of commercial cane sugar is lost during the harvest process due to compact, cane splitting, spraying etc… (Sugar Research Australia, 2016). Interestingly, the use of larger (and heavier) harvesters, which have helped labour and fuel costs, may have come at the cost of greater harvest losses.

Geographic Information Systems

Geographic Information Systems (GIS) are an essential foundational technology upon which many other technologies or decision support systems could be developed. GIS are software packages that allow users to:

- create and overlap numerous maps
- manage data associated with maps
- analyse and manipulate data from multiple map layers

Examples of data layers:

- soil type
- elevation (topography)
- crop yield
- crop quality
- field boundaries
- management zones
- remotely sensed imagery
- weed and pest locations
- historical land use

Variable Rate Nutrient Application

Nutrient management effects the productivity and environmental implications of sugarcane production. The industry has identified best-practice nutrient management as one of its key priorities:

> *"Best-practice nutrient management means having the best chance of success in minimising the risk of losses in productivity (loss of yield), profitability (loss of income), nutrients (leaching, run-off and/or gaseous losses) and soil resources (erosion and fertility losses)."* Sugar Research Australia, 2015

Currently, there is limited use of variable rate fertiliser application. However, some farmers are using soil maps to guide fertiliser application to the areas where it is needed most. The nature of the sugarcane crop limits the use of some variable rate techniques during the growing season. Once the plant reaches a certain height it becomes physically difficult to apply fertiliser.

Typically, fertiliser is applied in one major application at the start of the growing season and before the arrival of the wet season. Rainfall is needed to ensure plant uptake of nutrients, but inevitably there is a loss of nutrients due to runoff after heavy rain events. Given the promixity of the large production regions to the Great Barrier Reef the industry is facing increased scrutiny to limit nutrient runoff, which could damage the Reef. The industry has developed a 'Six Easy Steps' guide for effective nutrient management (CANEGROWERS). This involves:

1. Knowing and understanding your soils.
2. Undertaking and managing nutrient process and losses.
3. Regular soil testing.
4. Adopting soil-specific nutrient management guidelines.
5. Checking on the adequacy of nutrient inputs (e.g. leaf analyses).
6. Keeping good records to modify nutrient inputs when and where necessary.

The potential economic benefits of decision agriculture for the sugar industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the sugar industry.

Table A2.6: The potential economic impact of decision agriculture on the Australian sugar industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Fallow preparation	Selective spraying based on either real time sensing technology (e.g. weedseeker) or application maps based on previous weed history.	Reduction in intermediate inputs (chemical) of 4%	3.78	8.43
Crop rotation	Soil water sensing combined with seasonal forecasting analytics and impacts of previous crops etc giving more certainty to the most profitable crop rotation decisions (e.g. planting legumes as a break crop) and overall farming system planning. Potential benefits include improved soil health, reduced disease burden, improved nitrogen efficiency.	Overall productivity increase of 10%	55.09	152.56
Planting	Optimum row-spacing configuration to promote sugarcane growth and reduce operational variable costs (i.e. fuel).	At the same time: • Overall productivity increase of 10% • Intermediate costs reduced by 10%	74.11	234.58
Crop nutrition	Remote and proximal sensing technology for soil and plants in combination with aggregated and analysed multi farm data on nutrient status and yield provides recommendations for required nutrients for optimum yield. The timing of nutrient application is optimised to minimise leeching and runoff.	At the same time: • More and/or different fertiliser applied for greater yield and quality. 5% lift in output from increased spend on fertiliser. • The same amount of fertiliser applied but rate varied for optimum application rates. 5% lift in output with fixed fertiliser cost and efficiency gain spread across other inputs. • Less fertiliser applied using more precise application for the same yield. 5% reduction in fertiliser costs	97.61	82.58

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Fallow preparation	*Connectivity:* Current connectivity is largely sufficient to meet requirements. However, improvements will facilitate greater use of plant monitoring technologies (e.g. sensors) and data storage (i.e. cloud-based storage). *Data/ Decision Support:* Much of the technology associated with fallow preparation is real time and does not require integration with data and data analytics. Not a significant constraint. *Value Proposition:* Some technologies are commercially available. There is likely to be further international spill-over of technologies and business models. There are relatively low adoption rates of variable rate weed management but users are highly satisfied with results (i.e. further adoption is likely). *Legal/ Trust issues:* Large amounts of data sharing not required. Not likely to be a significant constraint.
Crop rotation	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils and weather information. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Potential to induce fundamental changes in cropping systems and rotations. Very large value proposition but will need buy in from growers to accept need for change. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Planting	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information and machine control. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Planting the right crop at the right time in the right place with the right rate is critical for maximising yield potential. Value proposition for getting this correct is significant. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Crop nutrition	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information and machine control. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets, particularly more granular soils information which is currently lacking. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Inappropriate nutrient application is one of the most common management induced yield constraints. Value proposition for appropriate nutrient application to maximise productivity and profitability is significant. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Crop protection and weed control	Targeted application of fungicides and pesticides directed by remote and proximal sensing combined with modelled and machine learned data.	Reduction in intermediate inputs (e.g. chemicals) by 4%. [2% weed control. 2% pesticide and fungicide control] "	9.53	41.06
Labour saving	Automation and robotics allows reduction in labour use. Electronic record keeping embedded in operations improves regulatory compliance.	Labour costs reduced by 12%	23.11	64.52
Harvest and processing scheduling	More accurate yield forecasting using remote sensed data allows for higher confidence levels in marketing programs, and improved harvest and processing scheduling.	Overall productivity improvement of 5%	27.59	76.37
		Total	**290.83**	**660.10**

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Crop protection and weed control	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information, plant sensing and machine control. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets and imagery. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Weeds and disease are significant drags on yield. Significant value proposition for technology which leads to more effective control. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Labour saving	*Connectivity:* Improved connectivity is essential for most in field labour saving technologies. *Data/ Decision Support:* Analysis of data is complex and time-consuming. Improved data management and new decision-support tools will help reduce farm labour requirements. *Value Proposition:* Adoption of labour saving technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Autonomous applications have legal and trust issues that are yet to be resolved. Does not necessarily require sharing of data throughout value chain.
Harvest and processing scheduling	*Connectivity:* Improved connectivity is essential for most in field efficiency improvement technology. *Data/ Decision Support:* Not a significant barrier as most efficiency improving technology will rely on real time information. *Value Proposition:* Adoption of efficiency boosting technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Not perceived to be a significant constraint.

Other impacts* on the sugar industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Market access and maintenance negotiation	Digital traceability and provenance systems providing confidence for end users. Maintaining and developing new high value markets for Australian sugar.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems do not rely on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance-based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Maintenance of markets and prevention of spread of pests.	*Connectivity:* Current connectivity status will be a barrier as real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. *Data/ Decision Support:* Not likely to be an impediment as relying on real time data. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance-based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Moderate sized market for new technologies (innovation likely to be driven by Australian initiatives).
- Relatively lower historical adoption of precision agriculture technologies than other cropping industries.
- Regulatory (e.g. Australian government environmental monitoring, such as nutrient run-off to the Great Barrier Reef).
- Consumer trends and global market requirements (e.g. Bonsucro initiative) likely to influence technology adoption and use of data on-farm/ across the supply chain.
- Long timeframes between plantings (i.e. ratooning after harvest) will limit the frequency of some decision agriculture practices (e.g. row-spacing and irrigation layout in light of given soil and nutrient data).

Horticulture (leafy greens, brassicas, carrots)

Sector Overview

The Australian vegetable growing sector is highly diverse in terms of the spread of production regions and climates. Vegetable growing is Australia's fifth-highest value agricultural industry in Australia, with the gross value of production valued at $3.4 Billion in 2014–15 (Savage, 2016).

Since the 1990s increases in average farm size and ongoing capital investment in new technologies have contributed to increased productivity and output (AUSVEG, 2012)

The vegetable supply chain involves a range of stakeholders including growers, packers, processors, marketers, wholesalers, agents, providores, retailers, and food service companies. The size of businesses varies enormously from small and medium sized growers through to major retail chains, and multinational agri-food corporations (including food processors, food service, and fast food restaurant chains) (AUSVEG, 2012).

The industry produces fresh produce (the major product in volume and value), fresh packed value-added products (a growing market segment driven by the consumer trend for convenience food), processed vegetables (frozen, canned and dried), ingredients for other food products, and dietary supplements.

Industry consolidation is affecting the competitiveness of Australian horticultural producers. In recent years, there has been increasing consolidation in the fresh produce retailing sector. The concentration of buying power in the hands of major supermarkets has put pressure on others in the supply chain. Increasingly, supermarkets are bypassing intermediaries, such as wholesale markets, and negotiating directly with farmers. The fragmented nature of the production sector means growers are competing heavily against each other to become price-takers from retailers (AUSVEG, 2012). Large supermarkets are also shaping the horticultural industry through the development of quality assurance schemes, product specifications, grading standards, and supply chain management (AUSVEG, 2012). For smaller growers, it is becoming increasingly difficult to compete with larger growers who can produce the large volumes demanded by supermarket contracts, and meet increasingly stringent product quality standards.

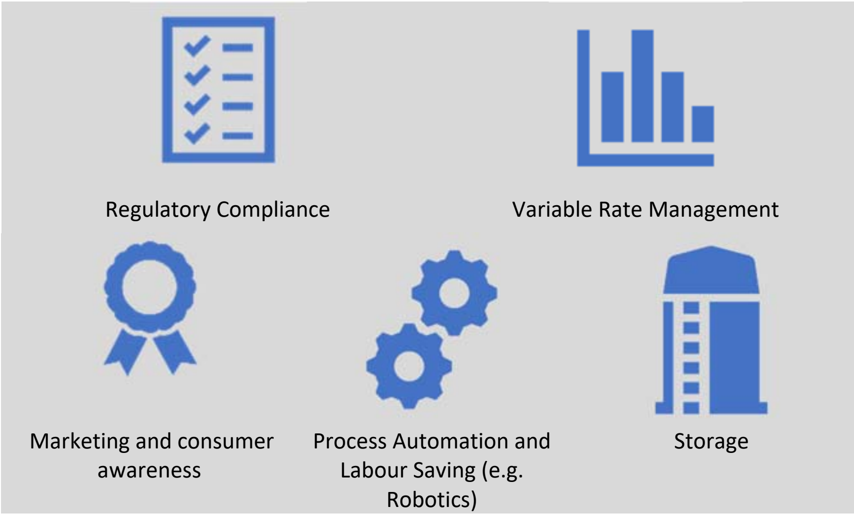
Australia is a relatively high-cost vegetable producer and given the relatively small domestic market is likely to face increasing competition from imports. In other words, reducing production costs is critical for remaining competitive among global markets (and thwarting imports).

This project is focused on the brassicas (e.g. broccoli, cauliflower, Brussel sprouts, cabbage), leafy greens, and carrot sectors. According to the Horticulture Innovation Australia Statistics Handbook the value of production for the year ending June 2015 was:

- Broccoli/ Baby Broccoli $122.5m
- Brussel Sprouts $22.1m
- Cabbage $44.1m

- Carrots $190.4m
- Cauliflower $48.9m
- Celery $50.2m
- Fresh Herbs $121.0m
- Head Lettuce $131.2m
- Leafy Asian Vegetables $62.5m
- Leafy Salad Vegetables $315.3m

Key Drivers of Decision Agriculture



Some of the major challenges faced by horticulture producers include the rising costs of inputs, the effects of variable climates, water, soil and labour shortages, and emerging pests and diseases.

At an industry-wide level there are significant opportunities for improving supply chain efficiencies through the use of digital technologies. There is a significant wastage of products across the supply chain, equivalent to about 15% of annual gross production.

Recent work has investigated the areas in which developments in automation, robotics, and sensing are likely to have the greatest on-farm impact. This includes a 2015–16 study that was undertaken by researchers from the CSIRO, Queensland University of Technology (QUT), Australian Centre for Field Robotics (ACFR) at the University of Sydney and the Variable Rate Technology (VRT) team from the Queensland Department of agriculture and Fisheries (Heiswolff, 2016).

The project developed a 'wish list' for potential applications of automation, robotics and sensing technologies in field and shed operations. In order of priority they were:

- **Automated crop health monitoring** for strategic targeted crop management based on various vision systems, imaging and sensor technologies to improve efficiency of field operations and better manage production risks. Further resourcing is needed to develop and test these technologies.

- **Autonomous weed management** for inter and in- row spraying/ weed eradication based on weed detection and identification using small autonomous platforms and various vision and sensing technologies. There have been a number of recent developments in robotics for the vegetable industry, including QUT’s AgBot 2, ACFR’s Ladybird and RIPPA robots.
- **Autonomous all purpose, adaptable** platforms that are flexible and suitable for a range of tasks across various terrains and farming operations using ‘plug and play’ interchangeable modules to spray, soil test and assess crop health. A step-by-step approach using existing platforms to test, develop and implement ‘modules’ of new technology might bring early benefits.
- **Sensing and sensor networks** for horticulture to improve field productivity. The technology has application across a range of field, shed and value chain situations including micro-climate monitoring in crops, quality monitoring and maturity testing, product tracking and vertebrate pest management. Some of this technology is already in use in agriculture, for example GPS auto-steer, multispectral imaging (NDVI), load cell yield monitoring and irrigation scheduling.
- **Robotic harvesting** of crops guided by crop forecasting, maturity assessment, vision systems, sensing, imaging, autonomous platforms, manipulators and grippers.
- **Increased packing line efficiency** – defect sorting before product enters the packing line.
- **Increased packing shed efficiency** – automated/robotic palletising and product tracking. For shed operations, the key driver is labour – how to reduce but also how to use technology to simplify packing decisions for staff where there is high turnover and low skill levels. Some technologies might be available ‘off-the-shelf’ from other regions or industries.
- **Managing vertebrate pests** in vegetable crops based on wireless sensor networks to detect and deter pests such as wallabies in tomato and birds in various crops.

The potential economic benefits of decision agriculture for the horticulture industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the horticulture industry.

Table A2.7: The potential economic impacts of decision agriculture on the Australian horticulture industry (leafy greens, brassicas, carrots).

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Paddock preparation	Selective spraying based on either real-time sensing technology (e.g. weedseeker) or application maps based on previous weed history.	Chemical (intermediate inputs) costs reduced by 15%	4.2	11.0
Planting	Variable rate seeding to plant optimum rate according to soil type, soil water status, and other environmental factors. Rate determined by combination of real-time sensed data (soil water status etc) and modelling/machine learned analysis of optimum rate for planting Time of sowing maximised for optimum yield informed by sensing of soil water conditions combined with medium and long-term weather analytics.	Overall productivity increased by 10%	70.0	188.7
Labour saving	Automation and robotics allows reduction in labour use during planting, crop monitoring and harvest.	Labour costs reduced by 30%	76.3	267.7
Crop Nutrition	Remote and proximal sensing technology for soil and plants in combination with aggregated and analysed multi farm data on nutrient status and yield provides recommendations for required nutrients for optimum yield. Variable rate application of fertiliser to minimise waste and optimise yield.	At the same time: • More and/or different fertiliser applied for greater yield and quality. 4% lift in output from increased spend on fertiliser. • The same amount of fertiliser applied but rate varied for optimum application rates. 4% lift in output with fixed fertiliser cost and efficiency gain spread across other inputs. Less fertiliser applied using more precise application for the same yield. 5% reduction in fertiliser costs.	103.1	77.3

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Paddock preparation	*Connectivity:* Current connectivity is largely sufficient to meet requirements. However, improvements will facilitate greater use of plant monitoring technologies (e.g. sensors) and data storage (i.e. cloud-based storage). *Data/ Decision Support:* Much of the technology associated with fallow preparation is real-time and does not require integration with data and data analytics. Not a significant constraint. *Value Proposition:* Some technologies are commercially available. There is likely to be further international spill-over of technologies and business models. There are relatively low adoption rates of variable rate weed management but users are highly satisfied with results (i.e. further adoption is likely). *Legal/ Trust issues:* Large amounts of data sharing not required. Not likely to be a significant constraint.
Planting	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information and machine control. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Planting the right crop at the right time in the right place with the right rate is critical for maximising yield potential. Value proposition for getting this correct is significant. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Labour saving	*Connectivity:* Improved connectivity is essential for most in field labour saving technologies. *Data/ Decision Support:* Analysis of data is complex and time-consuming. Improved data management and new decision-support tools will help reduce farm labour requirements. *Value Proposition:* Adoption of labour saving technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Autonomous applications have legal and trust issues that are yet to be resolved. Does not necessarily require sharing of data throughout value chain.
Crop Nutrition	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information and machine control. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets, particularly more granular soils information which is currently lacking. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Inappropriate nutrient application is one of the most common management induced yield constraints. Value proposition for appropriate nutrient application to maximise productivity and profitability is significant. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
In-crop weed and pest control	Targeted application of fungicides and pesticides directed by remote and proximal sensing combined with modelled and machine learned data. Targeted in crop control of weeds through remote or proximal sensing of weeds versus crop or map based spraying based on previous weed history.	Chemical use reduced by 15%	4.2	11.0
Storing vegetables	Monitoring/ remote sensing of vegetable condition reduces product wastage during storage.	Overall productivity increased by 20%	140.0	377.3
Regulatory compliance	Electronic record keeping embedded in operations.	Labour costs reduced by 2%	5.1	17.3
		Total	**402.8**	**950.8**

Source: AFI and HIA 2017.

Practice/ Decision	Effect of current constraints on likely realisation of benefits
In-crop weed and pest control	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information, plant sensing and machine control. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets and imagery. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Weeds and disease are significant drags on yield. Significant value proposition for technology which leads to more effective control. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Storing vegetables	*Connectivity:* Will require significant improvements in connectivity for in field component to make use of sensor networks for weather information and plant condition. Once produce in storage not as significant a constraint. *Data/ Decision Support:* Relies predominantly on real time data. Not likely to be a constraint since historical datasets not required. *Value Proposition:* Wastage in the horticulture industry is a significant drag on profitability through the entire value chain. Large incentive to use technology to reduce amount of waste. *Legal/ Trust issues:* To eliminate waste through the value chain will require transfer of data about produce. Trust issues could be a constraint.
Regulatory compliance	*Connectivity:* Will require significant improvements in connectivity for in field component of record keeping. *Data/ Decision Support:* Real time information. Analysis of historical datasets not required. *Value Proposition:* Adoption of efficiency boosting technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Possible trust barriers to be overcome in sharing electronic data with regulatory authorities.

Other impacts* on the horticulture industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Market access	Digital traceability and provenance systems providing confidence for end users in safety of vegetables.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems do not rely on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance-based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Maintenance of markets and prevention of spread of pests.	*Connectivity:* Current connectivity status will be a barrier as real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. *Data/ Decision Support:* Not likely to be an impediment as relying on real time data. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance-based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- High degree of integration across the value chain. On-farm technological change likely to be driven by the processing and retails sectors.
- Quality assurance requirements likely to drive on-farm and supply chain practices.
- New business models likely to emerge addressing high labour costs and quality assurance requirements.

Beef

Sector Overview

The uptake of digital agriculture in the Australian beef and cattle industry has lagged behind other industries, particularly intensive (e.g. poultry) and broadacre (e.g. cotton) industries. The extensive production systems of the Australian beef industry present some challenges and opportunities not present in industries with higher uptake of digital agriculture technologies.

More than 123,000 farms in Australia are engaged in cattle production, with those farms managing more than 75 per cent of Australia's agricultural land (MLA, 2016). Australia is the world's largest exporter of beef and one of the largest exporters of live cattle.

Beef is the single largest contributor by value to Australia's agricultural production. Production practices and business structures vary enormously, particularly between southern and northern Australia. The industry is large, diverse, complex and fragmented (ACCC, 2016). There are a range of different activities and channels through which cattle may be grown-out, sold, processed and reach an end market. Decisions affecting production and sales are influenced by several factors, including location, climate and size of operation.

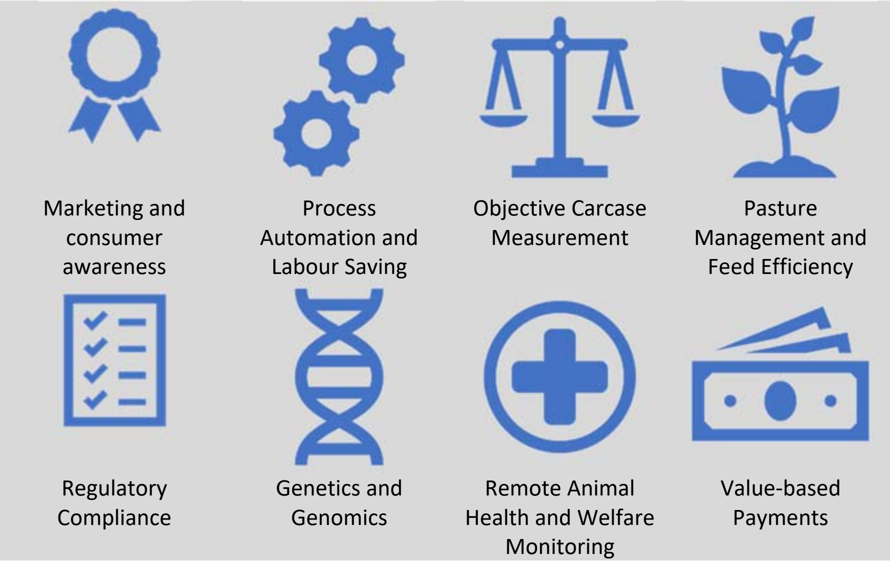
In 2016, MLA instigated the development of a red meat 'Digital Value Chain Strategy'. This strategy aims to enable the capture, integration and interpretation of data generated within the livestock industry through a range of new technologies. The strategy is designed to empower participants at every point in the value chain through data-driven decision making. The strategy is also considering cultural factors which will impact the way technology and innovations are adopted. The vision of the strategy is: *"By 2025, value chain stakeholders are connected through open sharing of data, utilising the world's best digital technology."*

There has been strong producer interest in the potential of new digital technologies. In northern Australia, technology adoption has targeted cost savings associated with improving labour efficiency, including remote (telemetry) water monitoring. In southern Australia, reflecting the fact that cattle are run alongside other enterprises such as sheep and cropping, there has been adoption of technologies and tools to improve pasture management. In both regions, the compulsory use of RFID tags has encouraged the collection of production data.

One of the biggest obstacles to widespread uptake of new technologies is the lack of connectivity infrastructure in regional and remote areas. Other factors affecting adoption include producer risk aversion, farm size versus technology cost, and a lack of tools developed for Australian extensive production systems.

In the coming years, there are likely to be major changes to the use of digital agriculture in the beef industry. Substantial industry investments in technologies (e.g. DEXA [Dual-energy X-ray absorptiometry] scanning) at the processing level will provide new information to producers that will likely affect production practices. The rise of objective carcase measurement has the potential to disrupt traditional business models and relationships between producers and processors. For example, the use of different marketing channels (e.g. saleyards, auctions, over-the-hooks) by producers could change as payment systems are based around objective measurement of single beef cuts.

Key Drivers of Decision Agriculture



The Australian beef industry is investing heavily in digital agriculture. Over the past few years the industry's service body MLA has initiated large long-term investments in areas such as objective carcase measurement, improving the functionality and effectiveness of integrity systems, increasing adoption of best management practices, and utilising spatial technologies (e.g. including precision satellite positioning, high resolution satellite imaging, autonomous and robotic vehicles, unmanned aerial vehicles and advanced databases)

In 2017, MLA launched its 'Digital Value Chain Strategy'. The key principles of this strategy are:

- **Making life easier:** a focus on improving the day-to-day operations of all stakeholders.
- **Openness:** provide the opportunity to access and reuse agreed data in more than one way to limit duplication.
- **Connections:** there is more value in linking information than isolated silos.
- **Trust:** improving the development of new solutions with limited restrictions.
- **Value chain focus:** utilising information within and across value chain segments.

The key objectives of the strategy are:

- **Increased profitability and productivity** through the effective use of new digital technologies.
- **Optimal value chain efficiency** through data linkages and agile decision-making.
- **Customer trust and confidence** through industry integrity and sustainability systems.

There are a range of areas where digital agriculture has the potential to improve the productivity and profitability of the Australian beef industry. For example, this includes:

- **Animal analytics** – The combination of location, health, remote weight gain monitoring and identification sensors allows analysis of the impacts of animal location, behaviour, genotype and the environment on health, growth and genetics.
- **Remote monitoring and automation** – Affordable remote monitoring using UAVs and telemetry allows automated collection of data about animals (e.g. weight, health) and assets, both on-farm and during processing and export. There are significant labour efficiencies to be gained.

One of the most exciting technological developments that is likely to occur in the beef industry is the development of objective carcase measurement technologies and feedback systems, which have the potential to have transform how beef is produced and priced. This would deliver benefits across the meat value chain. For example, it could help producers meet quality assurance standards and grading specifications. Non-compliance represents a huge cost and waste to the industry. Key areas of non-compliance include weight (under or over specification), fat (under or over specification), stress (pH and dark-cutting), and disease.

At an on-farm level, objective measurement could improve decision-making through:

- Real-time objective measurement at farm level by recording individual weight gain performance (day-to-day), animal-health and location. Possible technology solutions could include GPS-enabled or WiFi tags or walk-through weighers/scanners that could measure in body composition, fat levels or hormone levels to indicate pregnancy or finishing status.
- Real-time assessment of the feed base status to inform decisions on feeding options relative to livestock performance including moving paddocks, the need for supplementary feeding or selling off to reduce stocking rates.

This information could be combined and used with software decision support tools that could:

- assess and forecast carcass weight and performance against specification against a specific delivery window (that is, what proportion of the cohort will make specification by a certain date and those unlikely to do so)
- allow automatic drafting into consistent lines for either turn-off or finishing
- inform improved positioning of assets such as watering points and the relative performance of paddocks in terms of carrying and finishing capacity
- enable identification of animals with superior genetic traits to improve the herd or flock against specifications. Based on: (CIE, 2017).

The potential economic benefits of decision agriculture for the beef industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the beef industry.

Table A2.8: The potential economic impacts of decision agriculture on the beef industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Breeding decisions	Current: Sire/cow selection based on visual and objective measurements. Accurate genomic and genetic information accelerates genetic gain. Objective carcase measurement (OCM) feedback from processors allows producers to improve breeding decisions.	Overall productivity increased by 10% Additional productivity increase of 3%	661.7	1610.4
Feed, landscape and water management	Improved feedbase, water and landscape management. Soil fertility monitoring for improved pasture production. Feed allocation systems – allocating appropriate quality and quantity of feed to different classes of stock in a timely manner. Animal production monitoring – animal weight and body condition monitoring to improve reproductive performance and animal growth rates. Objective carcase measurement (OCM) feedback from processors allows producers to improve animal feeding and management decisions.	Overall productivity increased by 10% Additional productivity increase of 2%	610.8	1486.4
Animal health and disease monitoring	Early detection of subclinical diseases to improve performance and welfare.	Overall productivity increased by 5%	254.7	619.8
Labour saving	Automation and robotics allows reduction in labour use. Streamline/ automate/ digitise data collection and reporting to meet compliance requirements.	Labour costs reduced by 12%	161.3	502.6
		Total	**1688.5**	**4219.3**

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Breeding decisions	*Connectivity:* Current connectivity is largely sufficient to meet requirements. *Data/ Decision Support:* This is a major constraint. There will be challenges integrating multiple datasets including carcase performance (e.g. lean meat yield and eating quality), genetics/ genomics data, and lifetime performance data (e.g. animal health records). *Value Proposition:* The value proposition of OCM is well-recognised by producers. Technologies are becoming commercially available but are likely to require considerable further research/ trials, calibration/ validation etc. *Legal/ Trust issues:* There are potentially major issues with data sharing, including legal issues regarding access and ownership of OCM data, and logistical issues e.g. industry governance and coordination of datasets.
Feed, landscape and water management	*Connectivity:* Will require significant improvements in connectivity to make use of sensors for pasture, water, animal and weather information. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets (e.g. pasture/ feed availability, animal location, and climate models). Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* The value proposition is high for linking information on feed, landscape and water to make better management decisions (e.g. optimising stocking rates and paddock rotations). *Legal/ Trust issues:* Not likely to be a significant barrier.
Animal health and disease monitoring	*Connectivity:* Major improvements in connectivity are required to facilitate greater use of animal monitoring technologies (e.g. sensors) and data storage (i.e. cloud-based storage). *Data/ Decision Support:* Major improvements in data analytics capabilities are needed, particularly in area of predictive diagnostics. *Value Proposition:* The cost of data collection and analysis should be less than improvements to animal health. Should not be a barrier. *Legal/ Trust issues:* Not likely to be a significant barrier.
Labour saving	*Connectivity:* Improved connectivity is essential for most labour-saving technologies (e.g. remote monitoring and automation technologies). This is a significant barrier for the beef sector, particularly in remote pastoral regions where there is limited connectivity. *Data/ Decision Support:* Not perceived to be a barrier as will be relying on real-time data capture rather than analysis of historical datasets. *Value Proposition:* Labour is significant component of beef production. Value proposition high for technology enabling savings. *Legal/ Trust issues:* Automation does not require sharing of data throughout value chain. Trust issues should not be an impediment. Regulatory compliance will require sharing of data and may have trust constraints.

Other impacts* on the beef industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Traceability and food safety	Digital traceability and provenance systems providing confidence for end users in safety of Australian beef. Maintaining and developing new high value markets for Australian beef.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance-based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Maintenance of markets and prevention of spread of pests.	*Connectivity:* Real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. Large barrier for live export industry. *Data/ Decision Support:* Not likely to be an impediment as strong traceability systems exist from paddock to plate. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance-based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on the structural analysis of the sector and the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Large industry size and market for new technologies.
- Processor-led initiatives will drive adoption of new technologies (e.g. objective carcase measurement).
- There are significant differences in the scale of businesses in the sector, including large integrated pastoral companies in northern Australia and small cow-calf operations in southern Australia. Larger northern operations might have greater financial capacity to adopt new technology, but are also likely to face greater constraints (especially connectivity) than operations in southern Australia.
- Some of the greatest opportunities for decision agriculture will require major advances in data analytics capabilities. There is strong demand for business models that can link and analyse multiple layers of data (e.g. genetics, animal-health, and carcase performance) and support improved decision-making.
- MLA will play a critical role in implementing systems that ensure the integrity and fairness of digital industry systems (e.g. access to data regarding objective carcase measurement).

Sheepmeat

Sector Overview

Over the past 30 years the Australian sheepmeat industry has grown from being a by-product of the wool industry to become one of the country's largest agricultural export industries.

The Australian sheepmeat industry's competitive advantage is the ability to produce a high quality, safe product, which is traceable from paddock to plate (SCA, 2015).

International markets are critical to the future of the export-oriented Australian sheepmeat industry. Government policy must be focussed on working more closely with industry on a clear and cooperative strategy for increasing growth in exports that deliver improved returns on-farm.

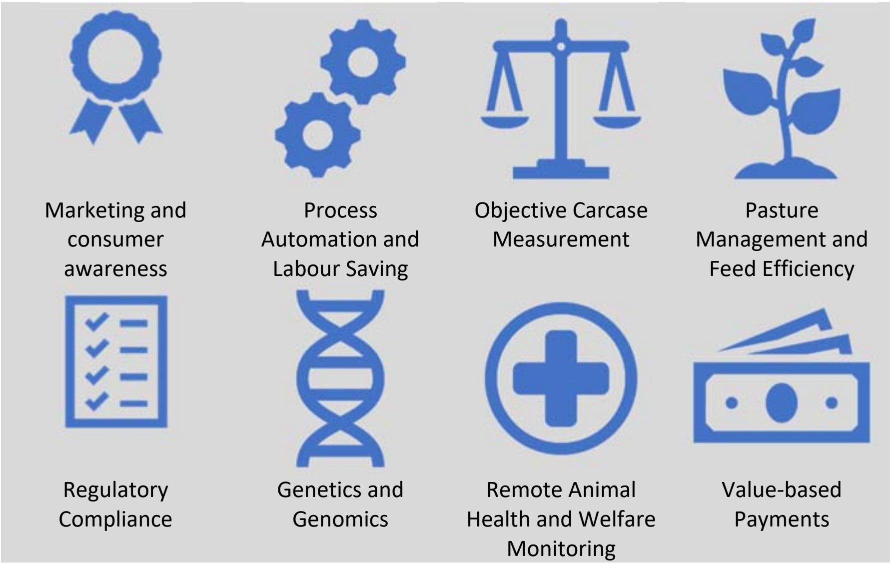
In the 1980's lamb attracted low prices, with fluctuating quality, and was considered an inferior product to other protein sources (SCA, 2015). In the 1990's the industry was worth approximately $1.1 Billion dollars and 85% was consumed domestically. Today Australia is one of the world's leading producers of lamb and mutton, the largest exporter of mutton and live sheep, and the second largest exporter of lamb. Australia exports 51% of its lamb and around 96% of its mutton. The off-farm meat value of the Australian sheepmeat industry is $3.9 Billion (SCA, 2015).

Productivity and profitability are determined by several interrelated factors. The choice of market, genetics, lambing and sale time, and all other inputs into the system are crucial to achieving a better combination of productivity, cost of production, and price received. The complexity of the interactions between these three things means that any one cannot be looked at in isolation.

Although productivity has increased over the past decade, this has come at ever increasing costs of production. The major cost for sheep flocks is the labour employed. According to the '2014 prime lamb situation analysis' report commissioned by MLA, labour remains the biggest cost of production for lamb producers, accounting for around 22% of the cost of production per kg. Increasing labour efficiency is one of the major competitive drivers for sheepmeat production.

Key Drivers of Decision Agriculture

The Australian sheepmeat industry has achieved major increases in productivity and profitability over the past twenty-five years. Digital technologies have the potential to drive further gains. The industry has a strong focus on improving value chain efficiency, across domestic and export markets. The industry is focused on premium markets which high quality, safe products, which are traceable from paddock to plate. The widespread adoption of objective carcase measurement technologies in abattoirs has the potential to drive transformational changes in several areas. This includes changing in the way producers are paid (e.g. value based marketing) and help producers manage animal performance and optimise livestock marketing. Objective measurement technologies have the potential to unlock significant improvements in sheep genetics, including increasing meat eating quality whilst maintaining or improving lean meat yield.



Key drivers for digital agriculture include:

- Improving regulatory compliance and making life easier for producers. This includes supporting the development, implementation and progressive roll-out of a fully integrated electronic system encompassing the National Livestock Identification System (NLIS), National Vendor Declaration (NVD), Livestock Production Assurance (LPA), National Sheep Health Monitoring Project (NSHMP), National Residue Survey (NRS), Sheep Health Statement (SHS) and Meat Standards Australia (MSA) for adoption on a voluntary basis.
- Improvements in sheepmeat eating quality while maintaining or improving lean meat yield. This includes increasing the number of animals meeting Meat Standards Australia (MSA) requirements.
- Improving animal health and welfare, including lamb survival
- Improving animal genetics, including reproduction rates, growth rates, and eating quality.
- Develop new technologies and management programs to increase pasture growth rates and persistence, and feed utilisation.

The potential economic benefits of decision agriculture for the sheepmeat industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the sheepmeat industry.

Other impacts* on the sheepmeat industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Market access and maintenance negotiation	Digital traceability and provenance systems providing confidence for end users in quality of Australian sheepmeat. Maintaining and developing new high value markets for Australian sheepmeat.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance-based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Maintenance of markets and prevention of spread of pests.	*Connectivity:* Real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. Large barrier for sheepmeat sector. *Data/ Decision Support:* Not likely to be an impediment as strong traceability systems exist from paddock to plate. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance-based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Moderate sized market for new technologies (innovation likely to be driven by Australian initiatives).
- Processor-led initiatives will drive adoption of new technologies (e.g. OCM).
- Potential high degree of synergies (and technological spillover) with the wool sector in technology.
- Opportunities for collaboration between the sheepmeat and wool sectors should be explored.

Table A2.9: The potential economic impacts of decision agriculture on the Australian sheepmeat industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Breeding decisions	[Current: Ram/ewe selection based on visual and objective measurements.] Accurate genomic and genetic information accelerates genetic gain. Easier identification of animal pedigree through cost-effective genetic tools and smart livestock tags. Objective carcase measurement (OCM) feedback from processors allows producers to improve breeding decisions. Additional 3% overall productivity increase for improved OCM breeding decisions	Overall productivity increase of 10% Additional productivity increase of 3%	176.9	438.8
Feed, landscape and water management	Improved feedbase, water and landscape management. Soil fertility monitoring for improved pasture production. Feed allocation systems – allocating appropriate quality and quantity of feed to different classes of stock in a timely manner. Animal production monitoring – animal weight and body condition monitoring to improve reproductive performance and animal growth rates. Objective carcase measurement (OCM) feedback from processors allows producers to improve animal feeding and management decisions. Additional 2% overall productivity increase for improved OCM animal management/ feeding decisions.	Overall productivity increase of 10% Additional productivity increase of 2%	163.3	405.0
Animal health and disease monitoring	Early detection of subclinical diseases through remote sensing technologies to improve performance and welfare.	Overall productivity increase of 10%	136.1	337.5
Labour saving	Automation and robotics allows reduction in labour use. Streamline/ automate/ digitise data collection and reporting to meet compliance requirements.	Labour costs reduced by 12%	39.9	134.8
		Total	**516.2**	**1316.1**

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Breeding decisions	*Connectivity:* Current connectivity is largely sufficient to meet requirements. *Data/ Decision Support:* This is a major constraint. There will be challenges integrating multiple datasets including carcase performance (e.g. lean meat yield and eating quality), genetics/ genomics data, and lifetime performance data (e.g. animal health records). *Value Proposition:* Technologies are becoming commercially available but are likely to require considerable further research/ trials, calibration/ validation etc. The value proposition of OCM is well-recognised by producers. *Legal/ Trust issues:* There are potentially major issues with data sharing, including legal issues regarding access and ownership of OCM data, and logistical issues e.g. industry governance and coordination of datasets.
Feed, landscape and water management	*Connectivity:* Will require significant improvements in connectivity to make use of sensors for pasture, water, animal and weather information. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets (e.g. pasture/ feed availability, animal location, and climate models). Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* The value proposition is high for linking information on feed, landscape and water to make better management decisions (e.g. optimising stocking rates and paddock rotations). *Legal/ Trust issues:* Not likely to be a significant barrier.
Animal health and disease monitoring	*Connectivity:* Major improvements in connectivity are required to facilitate greater use of animal monitoring technologies (e.g. sensors) and data storage (i.e. cloud-based storage). *Data/ Decision Support:* Major improvements in data analytics capabilities are needed, particularly in area of predictive diagnostics. *Value Proposition:* The cost of data collection and analysis should be less than improvements to animal health. Should not be a barrier. *Legal/ Trust issues:* Not likely to be a significant barrier.
Labour saving	*Connectivity:* Improvements in connectivity are required to support many labour-saving technologies (i.e. remote sensing and automation (e.g. watering points). This is a significant barrier for the sheepmeat sector as most production centres are located in areas of limited connectivity. *Data/ Decision Support:* Not perceived to be a barrier as will be relying on real-time data capture rather than analysis of historical datasets. *Value Proposition:* Labour is significant component of sheepmeat production. Value proposition high for technology enabling savings. *Legal/ Trust issues:* Automation does not require sharing of data throughout value chain. Trust issues should not be an impediment. Regulatory compliance will require sharing of data and may have trust constraints.

Wool

Sector Overview

Wool and sheep have been of historical importance to the Australian economy and have played a significant role in forging Australia's identity as a dominant supplier of premium quality products into international markets.

Wool production in Australia and around the world has declined in the last twenty-five years due to low wool prices and the perceived higher profitability of other enterprises, including cropping and lamb production. Since the collapse of the Reserve Price Scheme the Australian wool clip has tended to become genetically finer, which has led to an oversupply of and a reduction in the premium for superfine wool.

In the last two decades breeding ewes and lambs have increased as a proportion of the flock. A major driving factor has been increased prices for lamb and sheepmeat. Overall, there has been a transition from a wool-driven sheep industry to a dual-product wool plus lamb industry.

The relative profitability of wool compared to alternative land uses depends on commodity prices and seasonal conditions. While returns for wool enterprises have at times been lower than for lamb and cropping, over time the returns for wool tend to be less volatile.

There are relatively limited prospects for growth in wool supply, but there are opportunities in increasing the demand for wool products. Product quality, provenance and sustainability will assume increasing importance, as will animal welfare and ethical production practices, which will be required to maintain industry's social licence to operate.

The relative profitability of wool compared to alternative land uses depends on commodity prices and seasonal conditions. While returns for wool enterprises have at times been lower than for lamb and cropping, over time the returns for wool tend to be less volatile.

Over the last two decades, improvement in wool production has focused on improving product quality (principally by reducing fibre diameter) rather than quantity. Furthermore, sheep producers have increasingly shifted their focus from wool to meat production – not abandoning wool but moving from a sole wool focus to mixed farming enterprises, with wool being just one of their diversified product lines.

Specialist sheep and wool producers account for only about 30% of Australia's wool production with most wool and sheep meat production occurring on mixed enterprise farms, particularly on mixed livestock-crop industry farms (AWI, 2016).

Production

Australia's national sheep flock has declined dramatically since 1992–93. Wool's contribution to total Australian sheep GVP currently just under 50%. It is expected that the size of the national sheep flock will stabilise over the coming years and consequently, to maintain and grow wool's share, productivity gains will be required (AWI, 2016).

Productivity gains against static (real) production costs will lead to increased profits for farms growing wool.

The focus on increasing industry GVP acknowledges the need to align productivity developments across both wool and red meat production. While wool GVP is largely determined by the mean fibre diameter (MFD) and greasy fleece weight (GFW), meat GVP is largely determined by sheep turn-off rates and carcase weight (CWT). The key alignments for future investment will be in increasing lifetime weaning rates and lifetime wool cut as well as reducing weaner mortality. Opportunities also exist to increase productivity through improved stock management and to make life easier through labour saving technologies.

Of the 40,000 sheep businesses in Australia only 9,814 are Merino-based operations (ABS Census, 2011). Sheep farms are overwhelmingly small family-based businesses – averaging 2.1 FTEs, with 85% of sheep business labour being family labour. The high labour intensity of Merino enterprises remains a major challenge.

Australia's wool industry has many small wool growers. AWEX data shows that about a third of growers produce between 1 and 10 bales of wool. A much smaller number of larger growers produce the bulk of the clip. The largest 20% of growers produce 64% of the clip while the smallest 20% produce only 2%. The number of growers whose output exceeds 500 bales is quite small. AWEX data for sales in 2014/15 indicates approximately 130 growers who sold in excess of 500 bales (AWI Wool Selling Systems Review 2016).

It is anticipated that wool supply will remain tight into the future and unlikely that supply can increase significantly, given competing pressures (sheep turnoff for meat vs sheep retention for wool) (AWI, 2016). Delivering increased industry productivity and GVP will require:

- Increasing the lifetime reproductive productivity per ewe, whilst maintaining fleece weight, and so reduce wastage and increase feed utilisation efficiency.
- Proactively address welfare concerns, especially relating to invasive procedures (e.g. pre-operative pain relief)
- Reducing costs and impacts of vertebrate pests, diseases and parasites.

Processing and Exports

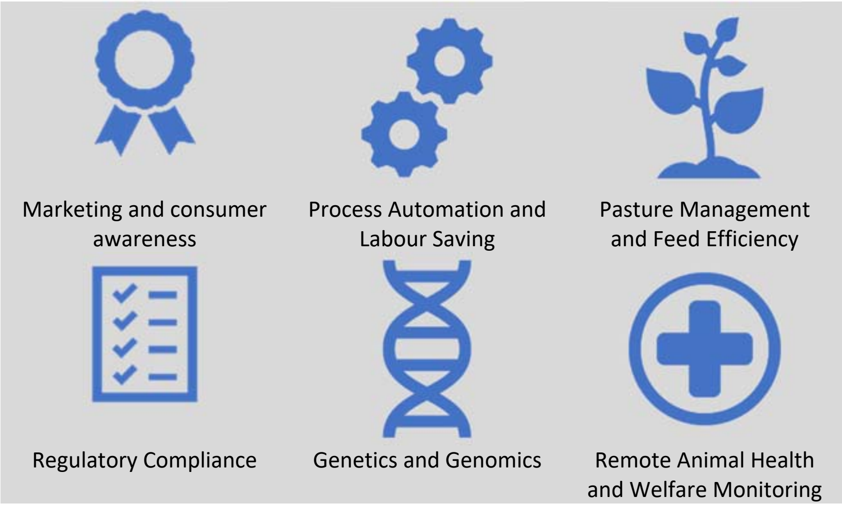
Over the last two decades, China has become the dominant buyer of Australian greasy wool taking around 74% of Australian exports on a value basis (AWI, 2016). Other major markets include Italy, the Czech Republic and India. China now dominates global exports of wool textiles with the US, UK, Japan and Italy being the largest importers. The 'casualisation' of fashion has reduced the demand for high-value woven wool wear, however there is strong demand for superfine wool in the growing active leisurewear market.

Consumption

Australia produces around 60% of all apparel wool (< 24.5 μm) and around 90% of the fine apparel wool (< 19.5 μm) (AWI, 2016). In terms of wool for apparel, Australia accounts for 46% of world production, with China accounting for 12%. For Merino wool, Australia's share is even higher with an estimated 80% of the world's wool production of 20 microns and finer (AWI, 2016).

The Western Hemisphere (Europe, the US & Japan) continues to be the dominant consumer of premium, high margin products and to set the design and quality agendas for the global consuming public. The Eastern Hemisphere (China, India, Southeast Asia) continues to drive volume growth in demand across all segments of the market, with the emergence of developing cities creating the most significant source of new demand for premium and luxury brands.

Key Drivers of Decision Agriculture



Key drivers of decision agriculture in the wool industry relate to meeting the following objectives:

- Improving animal health and welfare.
- Lifting the average weaning rate in Merino-Merino joinings.
- Reducing the impacts and costs of wild dog and other vertebrate pests.
- Increasing the genetic and phenotypic aspects of lifetime economic performance of ewes in wool enterprises.
- Strengthen wool's reputation for environmental stewardship.
- Improving supply chain efficiencies and reducing transaction costs (e.g. wool selling).
- Utilising satellite monitoring to improve pasture utilisation.
- Reducing labour requirements and improving occupational health and safety.

Labour use efficiency

Labour use efficiency is an important contributor to farm profitability, and seasonal labour availability constraints have been shown to limit important profit drivers such as stocking rate, but can also impact on sheep health and welfare. More significantly and specifically, the wool industry suffers by comparison to other livestock enterprises due to the frequency of hands-on sheep management and harvesting activities. There is strong demand for technologies that reduce labour requirements, such as remote flock, pasture and water monitoring systems.

Improving genetics and lifetime productivity

One of the major drivers of digital agriculture in the wool industry is to improve sheep genetics. The industry is developing data analytics tools to target selection and culling of ewes and rams to increase lifetime performance. This involves combining insight from lifetime fleece, body and reproduction data with genetics and genomics data. Another key driver is improving lamb survival and identifying maternal pedigree (i.e. determining which lamb belongs to which ewe). For example, the development of low-cost per head alternatives to genomic parentage technology in wide commercial use for mothering-up Merino lambs

Animal health and welfare

Digital technologies could potentially improve sheep animal health and welfare, such as through the detection of subclinical signs of disease and early to support early management intervention.

Sheep health and welfare challenges are estimated to cost the Australian sheep industry more than $2.0 Billion per annum in control, prevention and production costs, with reproduction-related conditions now accounting for 50% of all costs, given the rapid escalation of sheep meat values over the past decade (AWI, 2016). The most economically-important diseases affecting the sheep industry in Australia are: internal parasites (e.g. worms), flystrike; lice; post-weaning mortality; perennial ryegrass toxicity (PRGT); peri-natal mortality, and; virulent footrot.

Another important area impacting sheep health and welfare is the impact of vertebrate predation. Australian woolgrowers continue to face high levels of pressure on their operations from wild dogs and other vertebrate pests, particularly in areas where profitable control cannot be achieved without wider community engagement. Wild dogs kill and maim adults and lambs in Merino flocks, feral pigs predate on lambs and occasionally on adults; rabbits drastically reduce farm carrying capacity through competition for available feed on offer; and fox predation continues to reduce lambing percentages across Australia. Applications for digital technology include remote flock and pest monitoring devices.

The potential economic benefits of decision agriculture for the wool industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the wool industry.

Table A2.10: The potential economic impacts of decision agriculture on the Australian wool industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Breeding decisions	[Current: Ram/ewe selection based on visual and objective measurements.] Accurate genomic and genetic information accelerates genetic gain. Easier identification of animal pedigree through cost-effective genetic tools and smart livestock tags.	Overall productivity increased by 10%	118.9	288.4
Feed, landscape and water management	Improved feedbase, water and landscape management. Soil fertility monitoring for improved pasture production. Feed allocation systems – allocating appropriate quality and quantity of feed to different classes of stock in a timely manner. Animal production monitoring – animal weight and body condition monitoring to improve reproductive performance and animal growth rates.	Overall productivity increased by 10%	118.9	288.4
Animal health and disease monitoring	Early detection of subclinical diseases through remote sensing technologies to improve performance and welfare.	Overall productivity increased by 10%	118.9	288.4
Labour saving	Automation and robotics allows reduction in labour use. Streamline/ automate/ digitise data collection and reporting to meet compliance requirements.	Labour costs reduced by 12%	35.5	118.5
Product marketing	Digital connections with consumers provide information on animal welfare, product quality attributes and production system	Overall productivity increased by 5%	59.4	144.2
		Total	**451.5**	**1127.9**

Source: AFI and AWI 2017

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Breeding decisions	*Connectivity:* Current connectivity is largely sufficient to meet requirements. *Data/ Decision Support:* This is a major constraint. There will be challenges integrating multiple datasets including wool cut/ quality, genetics/ genomics data, and lifetime performance data (e.g. animal health records). *Value Proposition:* The value proposition for improved genetics is high. New, cost-effective tools to identify animal pedigree could accelerate genetic gains. *Legal/ Trust issues:* There is currently a low level of data sharing about animal genetics in the wool sector (e.g. limited use of Australian Sheep Breeding Values).
Feed, landscape and water management	*Connectivity:* Will require significant improvements in connectivity to make use of sensors networks for pasture, water, animal and weather information. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets (e.g. pasture/ feed availability, animal location, and climate models). Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* The value proposition is high for linking information on feed, landscape and water to make better management decisions (e.g. optimising stocking rates and paddock rotations). *Legal/ Trust issues:* Not likely to be a significant barrier.
Animal health and disease monitoring	*Connectivity:* Major improvements in connectivity are required to facilitate greater use of animal monitoring technologies (e.g. sensors) and data storage (i.e. cloud-based storage). *Data/ Decision Support:* Major improvements in data analytics capabilities are needed, particularly in area of predictive diagnostics. *Value Proposition:* The cost of data collection and analysis should be less than improvements to animal health. Should not be a barrier. *Legal/ Trust issues:* Not likely to be a significant barrier.
Labour saving	*Connectivity:* Improvements in connectivity are required to support many labour-saving technologies (i.e. remote sensing and automation (e.g. watering points). This is a significant barrier for the wool sector as most production centres are located in areas of limited connectivity. *Data/ Decision Support:* Not perceived to be a barrier as will be relying on real-time data capture rather than analysis of historical datasets. *Value Proposition:* Labour is significant component of wool production. Value proposition high for technology enabling savings. *Legal/ Trust issues:* Automation does not require sharing of data throughout value chain. Trust issues should not be an impediment. Regulatory compliance will require sharing of data and may have trust constraints.
Product marketing	*Connectivity:* Potentially a significant barrier given limited connectivity in many production regions. *Data/ Decision Support:* Not perceived to be a barrier as will be relying on real-time data capture rather than analysis of historical datasets. *Value Proposition:* Will require commercial pull-through. i.e. sustained price premiums for product with provenance, sustainability and traceability information. Value proposition may also be provided by reliving pain point of compliance with retailer requirements. *Legal/ Trust issues:* Potentially significant barrier given retail trends (e.g. product branding), and potential regulatory changes (particularly related to animal welfare and environmental impacts).

Other impacts* on the wool industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Market access and maintenance negotiation	Digital traceability and provenance systems providing confidence for end users in safety and quality of Australian wool. Maintaining and developing new high value markets for Australian wool.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Maintenance of markets and prevention of spread of pests.	*Connectivity:* Real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. Large barrier for live export industry. *Data/ Decision Support:* Not likely to be an impediment as traceability systems generally do not rely on historical data and analysis. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Moderate sized market for new technologies (innovation likely to be driven by Australian initiatives).
- Need for RDC (AWI) to partner with private sector to attract commercial activity to the sector.
- Potential high degree of synergies (and technological spillover) with the sheepmeat sector in technology.
- Opportunities for collaboration between the sheepmeat and wool sectors should be explored.
- Some of the greatest opportunities for decision agriculture will require major advances in data analytics capabilities. There is strong demand for business models that can link and analyse multiple layers of data (e.g. genetics, animal health, and carcase performance) and support improved decision-making.

Pork

Sector Overview

Production

The Australian pig industry has experienced a major transformation in the decades since the 1970s. The Australian pig industry prior to the 1970s consisted of a large number of very small-scale piggeries, many of which were operated as a second enterprise on dairy or grain farms. The emergence of specialist, larger scale piggeries was accelerated by a severe industry downturn in the early 1970s, by the rationalisation of the Australian dairy industry, and as a consequence of the mechanisation and increasing specialisation that occurred in the grains industry from the 1980s onwards. The introduction of modern pig housing and associated technologies enabled the efficient management of large-scale piggeries, as evidenced by the rapid increases that occurred in average herd sizes post 1990.

In 2015, there were approximately 270,000 breeding sows and gilts and annual slaughterings totalled 4,957,000 (ABARES 2016). The 17% of pig enterprises in the largest size category (1,000 + head) account for almost 90% of the total number of sows, and more than 90% of the total national pig herd. In contrast, smaller-sized enterprises are involved in boutique production for specific or local markets, whereas the larger-scale enterprises are more likely to be involved in supplying pigmeat processors or national distribution supply chains. A small, but significant (especially for biosecurity), section of the Australian pig herd is run by 'pig keepers' who manage less than 8 pigs. This represents around 8000 of Australia's 250,000 sows.

Processing

Around 85% of pigs are marketed via contracted or grid supply arrangements with major pig processor, while approximately 3–5% are sold via livestock saleyards (AFI 2016). Available data reveals there are approximately seven export pig abattoirs, at least seven domestic abattoirs and approximately twenty pig boning operations in Australia, with the domestic abattoirs generally being multi-species operations. As is the case more generally in Australia, consolidation has been occurring in the processing sector, as smaller and service facilities struggle for profitability and the larger operations become more dominant, but apart from one facility, the scale of Australian processing facilities is not comparable with overseas pig processing sectors.

Domestic Consumption

The domestic market is a critical market for the Australian pig industry, with competition in that market arising from other meats, and from imported processed and cooked pigmeat consumption of pig meat has more than doubled over the same period. Average annual pigmeat consumption reached 27.9kg per person in 2015 (ABARES). More than half of this is processed products such as ham, bacon and smallgoods, much of which is imported.

Imports

Australia is a large importer of pigmeat. Deboned pigmeat imports are allowed into Australia but must be cooked before sale. As a consequence, pigmeat imports in the Australian market are sold to consumers in the form of processed ham, bacon and other smallgoods, but not as fresh uncooked product. They do, however, directly compete with Australian fresh pork destined for the processed market in Australia, and in that way also impact the entire Australian market.

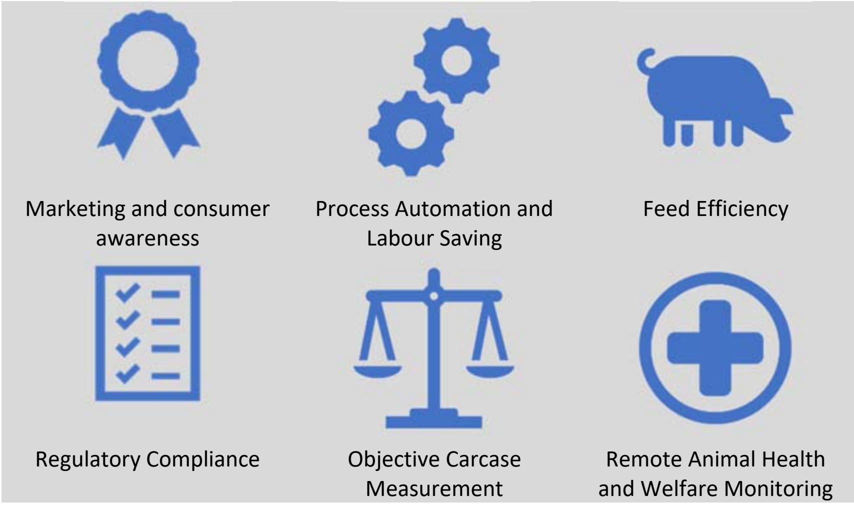
Australian pigmeat imports grew rapidly after quarantine changes were implemented in the late 1990s, and continued to grow each year until 2011, after which import volumes have fluctuated somewhat (AFI 2016). Denmark, the USA, Canada and the Netherlands have been the main source, collectively accounting for more than 90% of total imports. International disease incidents which limited exports from some nations (PEDv in the USA) and the depreciation of the Australian Dollar are likely to be key factor contributing to a slowing in the growth of imports in recent years, along with the fact that with imports comprising 70% of the cooked and processed pigmeat market, the market share occupied by imports is nearing market saturation levels and will be difficult to increase markedly (AFI 2016).

One of the major factors affecting the competitiveness of imported pigmeat products against Australian pigmeat products is the relative strength of the Australian Dollar. Imported pigmeat products have a very high market share in a number of categories, such as bacon and ham. Further growth in imports is likely to depend on movements of the Australian dollar. In the absence of activities or programs to protect the Australian industry, a higher Australian Dollar could lead to growth in imports (AFI 2016). Another factor that would dramatically change the level of imports is if changes to Australian quarantine laws were changed to allow the sale of uncooked, imported pigmeat. If this change was to occur it would be anticipated that there would be rapid growth in pigmeat imports, to the detriment of the Australian industry.

Exports

Export markets account for approximately 10% of Australian annual pigmeat production, with Singapore, New Zealand, Hong Kong, the Philippines and Papua New Guinea being the major export destinations and accounting for 90% of total exports in recent times. Australian pigmeat export volumes grew rapidly during the mid-late 1990s, peaking at a little over 90,000 tonnes (carcase weight equivalent) in 2002 before declining to current levels of approximately 50,000 tonnes cwe. Export growth prior to 2000 was attributed to disease outbreaks which limited supplies from other exporting nations. Pigmeat exports from these nations resumed in 2002, which, when combined with an appreciation of the $A exchange rate, resulted in a loss of export markets for Australian pigmeat. From 2003 to 2012, drought-induced high grain prices and for most of the period a high $A exchange rate reduced the competitiveness of Australian pigmeat exports on world markets.

Key Drivers of Decision Agriculture



The globalisation of pigmeat markets has resulted in major structural change in the pig production sectors of most nations, including Australia (AFI, 2016). This has brought into sharp focus the imperative of sustained productivity growth as a minimum requirement in order for national pig industries to remain competitive. Productivity improvements have been achieved via a range of different means, including;

- improved pig genetics, breeding technology, disease management and nutrition,
- improvements in pig housing and management systems,
- scale efficiencies associated with larger management units,
- efficiencies arising from specialisation
- vertical integration of production and processing systems, and
- increased efficiency in processing and transport.

Some of these improvements are associated with the successful adoption of research and development outcomes, while others are associated with changes at the enterprise level or along the supply chain.

The high degree of uniformity in pig production systems globally means that successful R&D in one particular location will quickly provide 'spillover' benefits for pig producers in other locations.

Decision agriculture has the potential to transform pork production in Australia over the next ten years, with other benefits across the value chain. There are likely to be significant opportunities in the following areas:

Production

- Genetics and Breeding
- Feed & Nutrition
  - Feed Conversion efficiency
- Animal Health, Disease and Mortality
  - Animal Husbandry Practices
  - Animal Monitoring
- Shed Monitoring
  - Heating, Humidity, Ventilation

    - Electricity, water use, and waste management

Processing and Value Chain efficiencies

- Product Quality
    - Improving compliance with customer specifications
    - Improving carcase utilisation
- Product Integrity
    - Biosecurity and Traceability

Marketing and Market Access

- Market Insights
- International Market Development
- Domestic Market Development

Governance, Compliance, and Sustainability

- Demonstrating sustainability (particularly environmental and animal welfare)
- Addressing Societal Needs (Maintaining the industry's 'Social License to Operate')

Production

- Genetics and Breeding
- Feed & Nutrition
    - Feed Conversion efficiency
- Animal Health, Disease and Mortality
    - Animal Husbandry Practices
    - Animal Monitoring
- Shed Monitoring
    - Heating, Humidity, Ventilation
    - Electricity, water use, and waste management

The potential economic benefits of decision agriculture for the pork industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the pork industry.

Other impacts* on the pork industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Market access and maintenance negotiation	Digital traceability and provenance systems providing confidence for end users in safety of pork. Maintaining and developing new high value markets for Australian pork.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance-based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Maintenance of markets and prevention of spread of pests.	*Connectivity:* Real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. Not likely to be a major barrier for the pork industry. *Data/ Decision Support:* May be a significant barrier because some gaps exist in industry datasets on the location and activities of very small-scale pig producers (including those in peri-urban regions.) *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Highly integrated value chain (on-farm technological change likely to be driven by the processing and retails sectors).
- High degree of homogeneity between Australian and international production systems.
- Australia is a relatively high-cost producer and the sector faces significant competition from cheap imports (particularly from northern Europe and North America).

Table A2.11: The potential economic impacts of decision agriculture on the Australian pork industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Animal health monitoring	Early detection of subclinical diseases through remote sensing technologies to improve performance and welfare.	Overall productivity increased by 5%	7.8	57.3
Efficient feeding systems	Current: Inefficient feeding systems Automated systems reduce feed wastage and help identify genetics with higher feed use efficiency	Feed costs reduced by 10%	8.5	80.9
Process automation	Current: Combination of automated and manual automation Automation and robotics allows reduction in labour use. Improved shed monitoring (heating, humidity, and ventilation). Streamline/ automate/ digitise data collection and reporting to meet compliance requirements	Labour costs reduced by 12%	2.8	26.9
Improved product quality and carcase utilisation	Current: Inconsistent product quality leads to inefficient processing. Reduced incidence of carcase non-compliance rates. Increased carcase utilisation.	Overall productivity increased by 3%	4.7	34.4
		Total	**23.7**	**199.5**

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Animal health monitoring	*Connectivity:* Current connectivity is largely sufficient to meet requirements, but improvements will facilitate greater uptake of remote animal monitoring technologies. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets (e.g. real-time animal health status). Lack of data and analytics capacity will be a critical constraint (e.g. predictive analytics to identify subclinical animal health conditions). *Value Proposition:* The cost of data collection and analysis should be less than improvements to animal health. Should not be a barrier. *Legal/ Trust issues:* Concerns about data sharing between producers and processors (given the latter's relative bargaining power in the supply chain) may limit adoption of animal health monitoring tools. E.g. producers may fear they will face discounts if they share animal health benchmarking data.
Efficient feeding systems	*Connectivity:* Current connectivity is largely sufficient to meet requirements. *Data/ Decision Support:* Data-intensive process, requiring information on individual animals… *Value Proposition:* Feed is a major component of production costs. The value proposition is high for technologies that improve feed efficiency. *Legal/ Trust issues:* Not likely to be a significant issue.
Process automation	*Connectivity:* Current connectivity is largely sufficient to meet requirements, but improvements will allow greater use of automation and robotic technologies. *Data/ Decision Support:* Challenges exist in integrating multiple datasets to meet compliance requirements. *Value Proposition:* Many products are available commercially in Australia and overseas markets. There is already high levels of automation in some production systems. Further adoption will be influenced by technology costs and demonstration of benefits. *Legal/ Trust issues:* Not likely to be a significant issue.
Improved product quality and carcase utilisation	*Connectivity:* Current connectivity is sufficient to meet requirements. *Data/ Decision Support:* Heavily dependent on the integration of several datasets and calibration of technology/ decision support tools. *Value Proposition:* Compliance with carcase quality specifications is a key driver of business performance. The value proposition is high for technologies that enable improved product quality. *Legal/ Trust issues:* Not likely to be a significant issue.

Dairy

Industry Overview

The Australian dairy industry is a $13.5 Billion farm, manufacturing and export industry (Dairy Australia, 2016).

In 2015, Australia's around 6,128 farmers milked a total of 1.74 Million cows producing 9.73 Billion litres of milk, with a farmgate value of about $4 Billion (Dairy Australia, 2016). Farmers sell milk mostly by direct contracts between the farmer and processor: either a fresh milk/ product processor (E.g. Lion, who focus on fresh products like drinking milk) or a dairy product and ingredients manufacture (e.g. Fonterra, who make a wide variety of fresh and processed products, such as milk powders).

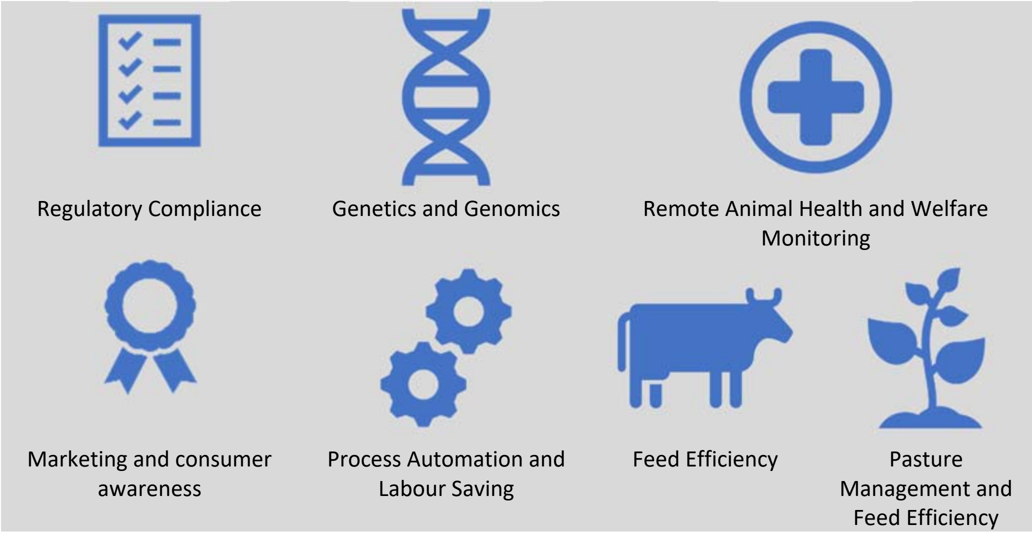
Dairy is Australia's fourth largest agricultural export industry by value. In 2014/15, dairy exports were worth around $2.9 Billion, with Asia accounting for 78% of exports (Dairy Australia 2016). Japan is Australia's largest single market by value ($483 Million or 17% of total export value), while China is the biggest market by volume (136,000 tonnes or 17% of export volume).

Table A2.12: The Australian dairy industry in 2014: key facts and figures.

National dairy herd	1.74 Million cows
Average herd size	284 cows
Total milk production	9.731 Billion litres
Average annual milk production per cow	5,730 litres
Total sector value (farm, manufacturing and exports)	$13.5 Billion
Dairy exports	$2.88 Billion 6% of world dairy trade 4th largest exporter 34% of production exported
Milk utilisation	Cheese 31% SMP and Butter 27% Drinking milk 25% WMP 8% Other 9%
Annual production of main commodities (tonnes)	Milk powders 332,900 Cheese 344,000 Butter 118,700
Major markets for Australian dairy products (tonnes)	Australia (inc. drinking milk) 3,033,000 Greater China 136,400 Japan 103,900 Singapore 86,600 Indonesia 59,400 Malaysia 51,100
Average per capita consumption	Drinking milk 105 litres Cheese 13.6kg
Dairy industry workforce	Direct employment of around 39,000

Source: Dairy Australia 2016

Key Drivers of Decision Agriculture



The key productivity opportunity for the Australian dairy industry is to enhance pasture utilisation and feed efficiency. It is likely that there will be continued development in farm automation and robotic technologies, and an expansion in the use of robotic milking systems. However, the biggest gains in productivity from the full utilisation of digital agriculture are likely to not be inside the dairy parlour, but out in the paddocks through improved pasture and feed management. The commercial development of 'virtual fencing' technologies could allow virtual herding of cows, assisting with grazing rotations and reducing labour costs.

There are many factors that influence the productivity and profitability of dairy farms in Australia, and a high degree of variation between different production systems. The main difference between average and top performers appears to be in making accurate and timely decisions. The best farmers seem to ‘get things more right, more often’. As a consequence, there is high demand for decision support tools that give farmers greater confidence.

There is potential for the spillover of technologies from overseas dairy industries (particularly Europe [Ireland and the Netherlands], the US, and NZ). However, there is a need to tailor these technologies to Australian conditions. For example, temperature monitoring devices that are commonly used in Europe to detect cows in-heat might not be appropriate for Australia's outdoor dairy systems – particularly during warmer summer months.

The potential economic benefits of decision agriculture for the dairy industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the dairy industry.

Table A2.13: The potential economic impacts of decision agriculture on the Australian dairy industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Production Sector impact on GVP ($m)	Processing & Manufacturing Sector impact on GVP ($m)	Impact on GDP ($m)
Breeding decisions	Current: Genetic selection based on estimated breeding values with limited understanding on the correlation with production costs. Accurate genomic and genetic information accelerates genetic gain. Breeding decisions informed by a greater understanding of lifetime productivity, including the relationship between milk output/ quality and feed intake. i.e. increased feed conversion efficiency.	Overall productivity increased by 10%	154.8	547.9	374.6
Variable rate pasture management	Current: Constant application rate across paddock. Variable rate pasture management reduces input costs and reduces the costs of purchased feed (more pasture/ feed is produced on farm reducing the reliance on external sources)	Overall productivity increased by 10%	154.8	547.9	374.6
Labour saving	Current: Labour intensive production practices e.g. milking. Automation, robotics and remote sensing allow reduction in labour use. Greater uptake of robotic milking systems.	Labour costs reduced by 30%	102.8	364.6	339.2
Animal health and disease monitoring	Current: Manual animal health monitoring; Reliance on highly trained stockpersons and veterinarians; Difficulties in early identification of animal health issues. Remote sensing and decision-support tools are used to help detect sub-clinical health issues and guide early intervention.	Overall productivity increased by 5%	77.4	274.0	187.3
Regulatory compliance	Current: costly (labour intensive), manual, and inefficient regulatory compliance. Streamline/ automate/ digitise data collection and reporting to meet compliance requirements	Labour costs reduced by 2%	6.9	24.3	22.6
		Total	**496.6**	**1758.7**	**1298.3**

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Breeding decisions	*Connectivity:* Current connectivity is largely sufficient to meet requirements. *Data/ Decision Support:* This is a major constraint. There will be challenges integrating multiple datasets including animal performance (e.g. milk production and animal health status) and genetics/ genomics data. *Value Proposition:* The value proposition is well-recognised by producers. *Legal/ Trust issues:* Not likely to be a significant barrier.
Variable rate pasture management	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information and machine control. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets, particularly more granular soils information which is currently lacking. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Improving pasture production and feed utilisation are key drivers of farm profitability. Value proposition likely to be high. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Labour saving	*Connectivity:* Improvements in connectivity are required to support many labour-saving technologies (i.e. remote sensing and automation). This is a significant barrier for dairy sector as most production centres are located in areas of limited connectivity. *Data/ Decision Support:* Not perceived to be a barrier as will be relying on real-time data capture rather than analysis of historical datasets. *Value Proposition:* Labour is significant component of dairy production. Value proposition high for technology enabling savings. *Legal/ Trust issues:* Automation does not require sharing of data throughout value chain. Trust issues should not be an impediment. Regulatory compliance will require sharing of data and may have trust constraints.
Animal health and disease monitoring	*Connectivity:* Major improvements in connectivity are required to facilitate greater use of animal monitoring technologies (e.g. sensors) and data storage (i.e. cloud-based storage). *Data/ Decision Support:* Major improvements in data analytics capabilities are needed, particularly in area of predictive diagnostics. *Value Proposition:* The cost of data collection and analysis should be less than improvements to animal health. Should not be a barrier. *Legal/ Trust issues:* Not likely to be a significant barrier.
Regulatory compliance	*Connectivity:* Improvements in on-farm connectivity will be critical to improving data collection and storage. *Data/ Decision Support:* Challenges exist in integrating multiple data sets. *Value Proposition:* Regulatory compliance is a significant cost. The value proposition is high for time/ labour saving technologies. *Legal/ Trust issues:* Not likely to be a major constraint.

Other impacts* on the dairy industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Market access and maintenance negotiation	Digital traceability and provenance systems providing confidence for end users in safety of dairy products. Maintaining and developing new high value markets for Australian dairy products.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance-based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Maintenance of markets and prevention of spread of pests.	*Connectivity:* Real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. Large barrier for the dairy industry. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance-based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Large market for new technologies (likely to attract new business models/ products from overseas).
- Globally significant industry.
- Likely direct technological spillover from New Zealand and Ireland (similar pasture-based systems).
- Technologies from some regions may need to be adjusted to suit Australian systems (e.g. hot summers and predominately pasture-based systems c.f. total mixed ration systems in northern Europe).

Eggs

Industry Overview

Production

Over the past twenty-five years there has been consolidation in the egg production. There are a small number of very large egg producers. At the same time, niche marketing and premiums for free range eggs have helped smaller farmers remain competitive with very large and integrated businesses. In June 2014, the ABS estimated that there were 252 egg farms in Australia. These farms are typically located near to feed sources and key markets.

Farm production systems include cage, barn-laid and free-range systems. Increasing consumer demand and community expectations are leading to a shift away from cage systems to free-range systems.

Intensive caged systems

Modern caged systems involve hens housed in controlled environment sheds with computerised microclimatic control. Hens are kept in welded wire cages with dimensions that satisfy the minimum standards of the *Prevention of Cruelty to Animals (Domestic Fowl) Regulations 2006*. Feeding, manure removal and egg collection are automated in many modern caged systems.

Cage based production is the most efficient and productive system and produces eggs at the least cost (Victorian Government, 2014). With price remaining a key consideration for consumers, this has been the dominant production system used by the industry. However, demand for cage-free eggs has grown as consumers are encouraged by the two big supermarket brands to take animal welfare issues into consideration.

Barn-laid systems

Barn production systems are predominantly automated deep litter systems where birds are free to move within a shed, but not outside. This eliminates the risks of predators, while allowing birds to nest, dust bathe and perch. It also reduces biosecurity risks associated with the transfer of diseases from wild birds to free range chickens that are outside the shed (Victorian Government, 2014). Shed sizes are generally around 10,000 hens. Barn systems are relatively new and a challenge remains in developing and improving the efficiency of management techniques and equipment.

Free-range systems

Free-range production systems provide birds with the ability to range or move around in both indoor and outdoor areas. Birds can nest, dust bathe, perch and move freely. Birds are also exposed to both natural and artificial lighting. Free-range commercial sheds range from 2,000 to 10,000 birds (Victorian Government, 2014). The semi-commercial backyard industry has shed sizes from 100 to 2000 birds. Free range production is costlier for several reasons including the greater area of land and labour required per bird.

Processing

The main market for eggs is the domestic shell market. This market accounts for around 80–85 per cent of all eggs consumed (Victorian Government, 2014). Most shell eggs are sold through retail chains. The remaining eggs are processed and sold either domestically, primarily to the food service sector, or exported. Egg products include egg pulp, liquid white, liquid yolk, dried white, boiled eggs, peeled eggs, omelette mix and scrambled egg mix. A small amount of eggs are supplied to the pharmaceutical industry (Victorian Government).

Exports

The Australian egg industry is primarily focused on the domestic market. In 2016 the value of egg products exported was approximately $3m, including fresh, dried, preserved, sweetened and albumin products (ABS).

There are opportunities to grow the value of Australian egg exports. This includes exploring opportunities for value-added manufactured egg products, as well as shell eggs. In 2017, an outbreak of avian influenza in South Korea created an opportunity for Australian egg exports, which are recognised for their food safety and traceability credentials.

Imports

Australia imports a small amount of egg products each year, worth approximately $21m in 2016CY (ABS). This is mostly comprised of manufactured egg products, including fresh, dried, preserved, sweetened and albumin products.

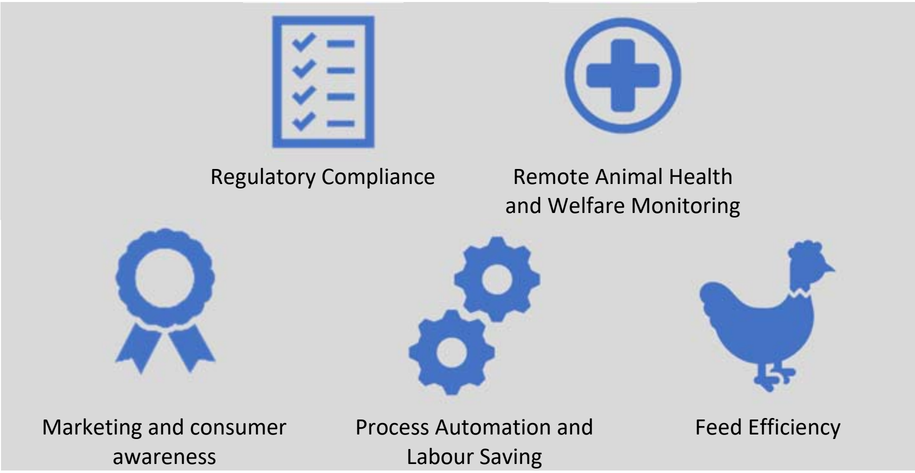
Consumption

The key driver for the Australian egg industry is per capita domestic consumption. Egg consumption in Australia has changed considerably over the last 70 years. Early in the 20th century per capita egg consumption in Australia was around 250 per annum (Victorian Government, 2014). However, between the 1940s and 1990s consumption declined by around 46 per cent. This fall was attributed primarily to the trend away from eggs in breakfast meals (due to changing social structures and a desire for convenient, ready-made meals such as cereal) and increased concerns about the health impacts of cholesterol (Victorian Government, 2014).

Apparent per capita consumption reached a low of 132 eggs per year in 1995–96 (Victorian Government, 2014). However, since that time the industry estimates that average consumption has increased to 226 in 2016. Reasons for this include industry marketing and education campaigns which have changed consumer perceptions of the health aspects of eggs, their versatility, ease of preparation and use as a cheap protein alternative to meat sources, as well as a change in advice on the health impacts of egg consumption on cholesterol levels.

There has also been increased differentiation in the shell egg products available to consumers. This has included the development of new value-added products, such as omega rich and organic eggs (Victorian Government, 2014). However, the key change over the last decade has been the increasing influence of production methods in the decision-making of consumers. While price remains the key influence (with caged eggs the cheapest), barn-laid and particularly free-range eggs have grown their share of the market in response to consumer perceptions and attitudes towards animal welfare (Victorian Government, 2014).

Key Drivers of Decision Agriculture



There is a high level of adoption of robotics and automation technologies in the egg industry. This includes feeding, transport, handling and packing of eggs and managing shed ventilation. It is expected that utilisation of robots will increase in the future as other capabilities are developed that improve the ability to remotely monitor birds.

Many tasks in the poultry industry were traditionally labour intensive and involved repetitive actions by workers, such as monitoring the health and welfare of birds, feeding birds, collecting eggs and removing manure. Mechanisation has enabled these tasks to be partially or completely automated. For example, feeding birds, removing manure and collecting, counting, grading and packing eggs has been largely automated. Robotics is also applied to controlling the shed environment. Fully automated systems are controlled by a computer which monitors various sensors for temperature, humidity, gas levels etc. Ventilation is managed by the computer to maintain the environmental parameters within the desired comfort levels.

There are rapid advances occurring in the application of robotics to the poultry industry. Robotics and automation has already improved production efficiency, particularly through reducing labour costs per bird. The intensive nature of most poultry enterprises makes the industry ideally suited to benefit from the utilisation of robotics.

The potential economic benefits of decision agriculture for the egg industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the egg industry.

Table A2.14: Potential impacts of decision agriculture on the Australian egg industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Production Sector impact on GVP ($m)	Post-Farm Gate impact on GVP ($m)	Impact on GDP ($m)
Animal health monitoring	Remote sensing and decision-support tools (tablets) are used to help monitor changes in animal behaviour and guide early intervention of health issues.	Overall productivity increased by 3%	3.3	23.1	34.8
Nutrition management	Better targeted nutrition and less wastage of feed	Feed costs reduced by 5%	3.5	31.8	29.2
Shed monitoring	Automation of shed monitoring (heating, humidity, and ventilation) and other tasks.	Labour costs reduced by 10%	1.7	16.0	19.0
Labour saving	Automation and robotics allows reduction in labour use. Electronic record keeping embedded in operations improve regulatory compliance (e.g. spray record keeping)	Labour costs reduced by 12%	2.1	19.2	22.8
Product marketing	Digital connections with consumers provide information on animal welfare, product quality attributes and production system	Overall productivity increased by 5%	5.5	38.6	58.0
		Total	**16.1**	**128.7**	**163.8**

Source: AFI and AECL 2017.

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Animal health monitoring	*Connectivity:* Current connectivity is largely sufficient to meet requirements. However, improvements will facilitate greater use of animal monitoring technologies (e.g. sensors) and data storage (i.e. cloud-based storage). *Data/ Decision Support:* Major improvements in data analytics capabilities are needed, particularly in area of predictive diagnostics. *Value Proposition:* The cost of data collection and analysis should be less than improvements to animal health. Should not be a barrier. *Legal/ Trust issues:* Concerns about data sharing between producers and processors (given the latter's relative bargaining power in the supply chain) may limit adoption of animal health monitoring tools. E.g. producers may fear they will face discounts if they share bird health benchmarking data.
Nutrition management	*Connectivity:* Current connectivity is largely sufficient to meet requirements. *Data/ Decision Support:* Data-intensive process. Requires individual animal needs. *Value Proposition:* This practice will require major developments in new technologies. Value proposition may be a barrier based on low margin per bird. *Legal/ Trust issues:* Will require greater transparency and trust between producers and retailers to share data on animal performance.
Shed monitoring	*Connectivity:* A high level of connectivity is essential for automation of shed monitoring. Full utilisation (remote monitoring) will require improved connectivity. *Data/ Decision Support:* Not perceived to be a barrier as will be relying on real time data capture rather than analysis of historical datasets. *Value Proposition:* Benefits will need to outweigh costs of sensors, robotics etc… *Legal/ Trust issues:* Does not require sharing of data throughout value chain. Trust issues should not be an impediment.
Labour saving	*Connectivity:* Improved connectivity is essential for most labour-saving technologies. Less of a barrier for chicken meat sector compared to other industries since most centres of chicken meat production are located in relatively well serviced areas for connectivity. *Data/ Decision Support:* Not perceived to be a barrier as will be relying on real time data capture rather than analysis of historical datasets. *Value Proposition:* Not perceived to be a barrier as will be relying on real-time data capture rather than analysis of historical datasets. *Legal/ Trust issues:* Labour is significant component of chicken meat production. Value proposition high for technology enabling savings.
Product marketing	*Connectivity:* Less of a barrier for egg sector compared to other industries since most production centres are located in relatively well-serviced areas for connectivity. *Data/ Decision Support:* Not perceived to be a barrier as will be relying on real-time data capture rather than analysis of historical datasets. *Value Proposition:* Will require commercial pull-through. i.e. sustained price premiums for product with provenance, sustainability and traceability information. Value proposition may also be provided by reliving pain point of compliance with retailer requirements. *Legal/ Trust issues:* Potentially significant barrier given highly integrated structure of the value chain (increasing consolidation in some parts of the chain), retail trends (e.g. product branding), and potential regulatory changes (particularly related to animal welfare and environmental impacts).

Other impacts* on the egg industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Traceability and food safety	Digital traceability and provenance systems providing confidence for end users in safety of eggs. Maintaining and developing new high value markets for Australian eggs.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Maintenance of markets and prevention of spread of pests.	*Connectivity:* Real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. Not likely to be a major barrier for the egg industry. *Data/ Decision Support:* Not likely to be an impediment as traceability systems only partially rely on historical data and analysis. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance-based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Highly integrated value chain (on-farm technological change likely to be driven by the processing and retails sectors).
- Relatively small number of commercial egg producers (approx. 250 in Australia).
- The several large integrated businesses (input supplying, production, egg collection and wholesaling) are best placed to benefit from decision agriculture.
- High degree of homogeneity between Australian and international production systems.
- There is already a high-level of automation and robotics in the sector.

Chicken Meat

Industry Overview

The Australian chicken meat industry has grown from humble beginnings as a mostly backyard enterprise to a large, sophisticated, intensive and highly integrated industry. The number of birds processed in 1951 was estimated at 3.1 Million, a fraction of the 594.2 Million processed in 2015 (Savage, 2016). Chicken meat is now the country's most consumed animal protein.

The Australian chicken meat industry is highly intensive and is well advanced in terms of the use of digital technologies. Technology developments have drastically reduced the costs of traditionally labour intensive tasks and allowed the scale of farms to substantially increase. These technologies include automation of key tasks such as feeding, shed condition and animal monitoring. There are significant opportunities to further improve the productivity of the chicken meat industry particularly through technologies that allow real-time monitoring of animal health and performance.

Production

Most commercial chicken meat farms are intensive, highly mechanised operations that form part of an integrated supply chain. In 2011, it was estimated that there were around 800 contract meat chicken growing farms (ACMF, 2011). Farms are typically located close to regional centres, where labour is available for processing. Production variability is low due to technical advances in nutrition and animal health.

There is a high level of vertical integration in the Australian chicken meat industry. This vertical integration means that large operations own or are in control of most aspects of the supply chain.

The majority of chicken meat produced in Australia (around 80%) is done under contracts made between processors and growers (ACMF, 2011). These growers own the farm and provide the management, shedding, equipment, labour, bedding and other inputs for the rearing of the chickens. The processing company owns the chickens at all times and provides the grower with feed, medication and technical advice. Contract growers are paid a growing fee which varies (between 59–73 cents) per bird and generally include a performance-based component (ACMF, 2011). Prices are influenced by large contracts between processors and supermarkets or the food service industry. Margins are typically low per bird, requiring growers (farmers) to produce high volumes of birds.

A completely vertically integrated company would operate:

- Feed mill – producing feed for breeders and meat chickens
- Breeding farms – producing fertile eggs
- Growing farms – producing the end-product i.e. chicken meat
- Processing plant – to process and market chicken meat
- Veterinary services
- Transport

The number of people working within the industry is estimated to be approximately 40,000. In addition to this, a further 100,000 jobs are estimated to be directly dependent on the industry (ACMF, 2011). These employment opportunities are in areas as diverse as farming, hatchery management, poultry processing, feed preparation, food processing, distribution, management, administration, quality control, research and development and veterinary services. Many people are direct employees of the chicken meat processing companies, but employment in this sector also includes contract roles in farming, transportation and other services that support the poultry industry.

Processing

Well over 95 per cent of the chicken meat grown and eaten in Australia is produced by seven privately owned Australian chicken meat processing companies. The two largest, Baiada Poultry and Inghams Enterprises, supply more than 70 per cent of Australia's chicken meat, with the next five companies each supplying between 3–9 per cent of the market (NSW DPI, 2012).

The relatively concentrated nature of the industry is matched by its small direct customer base (i.e. the supermarket chains and major quick service restaurant chains), as chicken is purchased from processors by a small number of major companies with substantial market power (ACMF, 2011). This concentration of market power in the hands of retailers and processors raises the potential of competition issues. Chicken growers are typically price takers from large processing companies, who themselves face their prices squeezed by large retailers (e.g. the major supermarkets). These industry structural issues ultimately influence the ability of chicken growers to realise the benefits of investment in decision agriculture technologies.

Key Drivers of Decision Agriculture

There is a high level of adoption of robotics and automation technologies in the chicken meat industry. This includes feeding, transport, handling, and animal and shed monitoring. It is expected that utilisation of robots will increase in the future as other capabilities are developed that improve the ability to remotely monitor birds.

Many tasks in the poultry industry were traditionally labour intensive and involved repetitive actions by workers, such as monitoring the health and welfare of birds, feeding birds, and removing manure. Mechanisation has enabled these tasks to be partially or completely automated. For example, tasks such as feeding birds and removing manure are now fully automated in some production systems.

Fully automated systems are emerging and continuing to reduce labour requirements. These include computer-controlled systems drawing data from various sensors for temperature, humidity, gas levels etc. For example, managing ventilation to maintain the environmental parameters within the desired comfort levels.

One of the overarching aims of decision agriculture in the chicken meat industry is the continuous monitoring of birds, including real-time monitoring of production (e.g. growth rates), health and welfare. This will support the early detection of disease and welfare problems and minimise production losses. It is likely that robots won't be able to monitor all birds, so attention will be focused on sentinel birds. This could include fitting sentinel birds with remote sensing devices.

There are number of areas in which there are likely to be developments in decision agriculture including:

- Monitoring of sheds and automation of systems e.g. feed, bedding, water, temperature, humidity, animal health, ventilation, lighting.
- Biosecurity and pest management.

The potential economic benefits of decision agriculture for the chicken meat industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the chicken meat industry.

Table A2.15: Potential impacts of decision agriculture on the Australian chicken meat industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Production Sector impact on GVP ($m)	Processing & Manufacturing Sector impact on GVP ($m)	Impact on GDP ($m)
Animal health monitoring	Remote sensing and decision-support tools are used to help monitor changes in animal behaviour and guide early intervention of health issues.	Overall productivity increased by 5%	9.2	97.6	67.0
Nutrition management	Better targeted nutrition and less wastage of feed. Feed accounts for around 60% of total costs.	Feed costs reduced by 5%	9.7	81.3	91.9
Shed monitoring	Automation of shed monitoring (heating, humidity, and ventilation) and other tasks.	Labour costs reduced by 10%	4.9	53.1	45.8
Labour savings	Automation and robotics allows reduction in labour use. Electronic record keeping embedded in operations improve regulatory compliance (e.g. spray record keeping).	Labour costs reduced by 12%	5.8	63.7	54.9
Product marketing	Digital connections with consumers provide information on animal welfare, product quality attributes and production system	Overall productivity increase by 5%	15.4	162.6	111.7
		Total	**45.0**	**458.3**	**371.4**

Source: AFI and RIRDC 2017.

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Animal health monitoring	*Connectivity:* Current connectivity is largely sufficient to meet requirements. However, improvements will facilitate greater use of animal monitoring technologies (e.g. sensors) and data storage (i.e. cloud-based storage). *Data/ Decision Support:* Major improvements in data analytics capabilities are needed, particularly in area of predictive diagnostics. *Value Proposition:* The cost of data collection and analysis should be less than improvements to animal health. Should not be a barrier. *Legal/ Trust issues:* Concerns about data sharing between producers and processors (given the latter's relative bargaining power in the supply chain) may limit adoption of animal health monitoring tools. E.g. producers may fear they will face discounts if they share bird health benchmarking data.
Nutrition management	*Connectivity:* Current connectivity is largely sufficient to meet requirements. *Data/ Decision Support:* Data-intensive process. Requires individual animal needs. *Value Proposition:* This practice will require major developments in new technologies._Value proposition may be a barrier based on low margin per bird. *Legal/ Trust issues:* Will require greater transparency and trust between growers and processors to share data on animal performance.
Shed monitoring	*Connectivity:* A high level of connectivity is essential for automation of shed monitoring. Full utilisation (remote monitoring) will require improved connectivity. *Data/ Decision Support:* Not perceived to be a barrier as will be relying on real-time data capture rather than analysis of historical datasets. *Value Proposition:* Benefits will need to outweigh costs of sensors, robotics etc… *Legal/ Trust issues:* Does not require sharing of data throughout value chain. Trust issues should not be an impediment.
Labour savings	*Connectivity:* Improved connectivity is essential for most labour-saving technologies. Less of a barrier for chicken meat sector compared to other industries since most centres of chicken meat production are located in relatively well serviced areas for connectivity. *Data/ Decision Support:* Not perceived to be a barrier as will be relying on real-time data capture rather than analysis of historical datasets. *Value Proposition:* Labour is significant component of chicken meat production. Value proposition high for technology enabling savings. *Legal/ Trust issues:* Automation does not require sharing of data throughout value chain. Trust issues should not be an impediment. Regulatory compliance will require sharing of data and may have trust constraints.
Product marketing	*Connectivity:* Less of a barrier for chicken meat sector compared to other industries since most centres of chicken meat production are located in relatively well serviced areas for connectivity. *Data/ Decision Support:* Not perceived to be a barrier as will be relying on real-time data capture rather than analysis of historical datasets. *Value Proposition:* Will require commercial pull-through. i.e. sustained price premiums for product with provenance, sustainability and traceability information. Value proposition may also be provided by reliving pain point of compliance with processor requirements. *Legal/ Trust issues:* Potentially significant barrier. Competition issues, market power, branding, regulatory changes (particularly related to animal welfare and environmental impacts).

Other impacts* on the chicken meat industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Traceability and food safety	Digital traceability and provenance systems providing confidence for end users in safety of chicken meat.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues.	*Connectivity:* Real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. *Data/ Decision Support:* Not likely to be an impediment as relying on real-time data. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Highly integrated value chain. On-farm technological change likely to be driven by the processing and retails sectors,
- High degree of homogeneity between Australian and international production systems.
- Incentives for small-medium sized growers to adopt new technologies are likely to be low unless there is supply chain pull-through (e.g. higher prices).

Wine

Industry Overview

The Australian wine industry tripled in size between 1991 and 2007. The total area of grapevines planted increased from 62 454 hectares in 1995 to a peak of 166 197 hectares in 2008 (Anderson and Aryal 2015). In the last ten years the industry has struggled with a ‘structural mismatch of supply and demand’. In 2009, it was estimated that Australia was producing 20–40 Million cases a year more wine than it was selling. Since 2009, demand for Australian wine has generally fallen due to a variety of international factors, including:

- the high Australian dollar;
- economic turbulence in overseas markets;
- an oversupply of grapes within the European Union;
- competition with new low-cost producers (including Chile, Argentina and South Africa); and
- a decline in consumer interest in Australian wine in key international markets including the United Kingdom and the United States.

Despite this there has been strong growth in Australian wine exports to China, particularly for red wine. This has given the industry some optimism about the future. China is the largest importer of Australian wine in every price segment above $10.

In the twelve months to March 2017, the value of Australian wine exports grew by 10 per cent to $2.3 Billion and volume increased by 5 per cent to 769 Million litres. Export value growth was driven by bottled exports, which grew by 12 per cent to $1.68 Billion and the value grew by 3 per cent to $5.47 (Wine Australia). The biggest growth product was Shiraz, which increased by 19 per cent in value and 10 per cent in volume (Wine Australia).

There are approximately 5,160 wine grape growers in Australia, with a vineyard area covering 135,178ha (ABARES 2016). These growers supply around 2,900 wineries. The industry is a major employer, supporting 172,736 full and part time jobs (ABARES 2016). This includes direct employment of 68,395 people and a further 104,341 full and part time jobs due to flow-on effects (e.g. wine retail jobs). Wine production directly employs around 16 186 people in Australia. AGWA advised that in 2012 the industry provided a further 7,500 jobs in grape growing.

Production costs, grape characteristics, yield and price all vary significantly between warm and cool climate regions. The committee heard that warm inland regions have 'higher water, fertiliser and herbicide costs', but lower labour and contract costs due to the use of mechanical harvesting systems. Warm regions typically produce 'significantly more grapes per hectare' which allows for 'spreading production costs' and typically receive lower prices

Australia's four largest wine producers—Accolade, Pernod Ricard Australia, Treasury Wine Estate and Casella Wines Pty Ltd—collectively accounted for around 39.3% of industry revenue in 2015–16.

The Australian wine industry is highly export-orientated. Around 60% of Australian wine is exported. Wine is the 'fifth largest agricultural exporting sector' in Australia and Australian wines are available in over 100 countries. The major markets are Europe, North America and Asia. Wine exports were worth approximately $2,183.9m in 2015–16.

Key Drivers of Decision Agriculture

The general driver of new digital technologies is to provide more accurate and timely information about yield, crop condition and quality information at the critical periods where growers can make management responses.

The Australian wine industry is currently making significant investments in projects that hope to advance the development of digital technologies and improve the productivity of vineyards. This includes improving the accuracy and timeliness of yield predictions through the use of spectroscopy. It is hoped that new tools, such as portable hand-held scanning devices, will be developed to assist growers in making informed pruning decisions and improve yields. This could help to reduce the economic losses due to late season bunch removal or reduced prices due to excessively high yields.

The adoption of precision viticulture technologies is currently constrained by perceptions of high costs, large time requirements, and limited technical support.

Extreme weather (e.g. heatwaves and frost events) can have a huge impact on grapevines and fruit production. It is expected that climate change will lead to an increase in extreme weather events. There are currently few tools that deliver the micro-sale information needed by growers to help predict, monitor and manage extreme weather such as high temperature. The industry is currently investing in tools that will help to deliver accurate and close to real-time information on temperature for individual vineyards and under canopies of individual plants. This information could be used to tailor management responses such as irrigation.

The potential economic benefits of decision agriculture for the wine industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the wine industry.

Other impacts* on the wine industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Regional branding	Using data to quantify terroir so that easier to describe attributes of regions and link to quality premiums.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Traceability and food safety programs	Digital traceability and food safety programs to provide assurance of the quality of Australian wine and help maintain access to markets.	*Connectivity:* Real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. Large barrier for live export industry. *Data/ Decision Support:* Not likely to be an impediment as relying on real-time data. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Australia is a major player in the global market.
- Technological spillover from other sectors is likely (e.g. remote sensing and UAVs from horticulture sectors).
- Highly integrated value chain (on-farm technological change likely to be driven by the winemaking sector).
- The value proposition for new technologies is different to most sectors. The focus is on optimising quality and not quantity (i.e. Meeting quality specifications rather than chasing yield gaps).

Table A2.16: The potential economic impacts of decision agriculture on the Australian wine industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Planting	Environmental data combined with climate modelling to more certain decision making about where to plant new vines to maximise variety by environment interaction.	Overall productivity improvement of 10%	76.76	94.52
Pruning	Pruning determines bunch number for the following year and can impact on disease susceptibility and vine health through canopy architecture. Imaging of vine canopies combined with ongoing analysis of how canopy structure determines yield/quality can inform more accurate pruning processes and potentially lead to automated pruning.	Pruning determines bunch number for the following year and can impact on disease susceptibility and vine health through canopy architecture. Imaging of vine canopies combined with ongoing analysis of how canopy structure determines yield/quality can inform more accurate pruning processes and potentially lead to automated pruning. Management of canopies for optimum yield and quality can reduce disease incidence. Overall productivity improvement of 10%	76.76	94.52
Irrigation and nutrient application	Water and nutrients applied are applied to vines to maximise the yield of grapes while maintaining quality targets. This is a complex interaction that can have big financial implications if quality targets are missed. Real time proximal and remote sensed data of soil condition, canopy size, vine health and bunch number information can be aggregated and analysed to inform water and nutrient application to maximise ability to hit desired yield and quality targets.	Overall productivity improvement of 10% Boost in quantity of grapes hitting yield and quality targets.	76.76	94.52
Labour saving	Automation and robotics allows reduction in labour use. Electronic record keeping embedded in operations (reduced cost of regulatory compliance for spray record keeping etc)	Labour costs reduced by 12%	20.34	30.10

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Planting	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* Planting the right vines the right place is critical for maximising quality and yield potential. Value proposition for getting this correct is significant. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Pruning	*Connectivity:* Will require significant improvements in connectivity to make use of sensor networks for soils, weather information. *Data/ Decision Support:* Heavily dependent on analysis of multiple data sets. Lack of data and analytics capacity will be a critical constraint. *Value Proposition:* The vine pruning process is critical for maximising quality and yield potential. Value proposition for getting this correct is significant. *Legal/ Trust issues:* Likely to be a significant constraint due to requirement to accumulate multiple datasets for analysis.
Irrigation and nutrient application	*Connectivity:* Improvements in farm-wide connectivity will facilitate the uptake of remote/ proximal sensing technologies and automation of water management. *Data/ Decision Support:* Improvement to weather and climate forecasting is needed to unlock full potential of water management technologies. This could be achieved through better integrating public and private (e.g. farm) data sets and improving spatial resolution of forecasting. *Value Proposition:* Producers are heavily focused on improving water efficiency. Increased adoption of water saving technologies is likely to occur as cost-benefits become clear (e.g. reduced water costs and increased yields and quality) *Legal/ Trust issues:* Not likely to have major impacts.
Labour saving	*Connectivity:* Improved connectivity is essential for most in field labour saving technologies. *Data/ Decision Support:* Analysis of data is complex and time-consuming. Improved data management and new decision-support tools will help reduce farm labour requirements. *Value Proposition:* Adoption of labour saving technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Autonomous applications have legal and trust issues that are yet to be resolved. Does not necessarily require sharing of data throughout value chain.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Consumables ordering for winemaking process	Wine grape yields can vary enormously (up to 40%) from year to year resulting in a large impact on consumables such as wine barrels that are required for the wine making process. More accurate yield prediction can make this process more efficient.		299.85	180.11
Grape movements and logistics for winemaking	Wineries have fixed capacity for winemaking. Unanticipated variation in yield can lead to the need to export/import grapes (to/from other wine regions or wineries). More accurate determination of through sensing can build efficiencies into this process.	Winemaking efficiency improvement. Overall productivity improvement of 10%	78.51	42.01
Grape Harvest	Data on grape quality can be used to program harvest sequences so that larger batches of uniform wine can be fermented.	Overall productivity improvement of 10%	76.76	94.52
		Total	**705.76**	**630.27**

Source: AFI and Wine Australia 2017.

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Consumables ordering for winemaking process	*Connectivity:* Improved connectivity is essential for most in field monitoring leading to supply chain efficiencies. *Data/ Decision Support:* Not a significant barrier as most efficiency improving technology will rely on real time information. *Value Proposition:* Adoption of efficiency boosting technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Will require data transfer between growers and processors. Trust issues could be a constraint.
Grape movements and logistics for winemaking	*Connectivity:* Improved connectivity is essential for most in field monitoring leading to supply chain efficiencies. *Data/ Decision Support:* Not a significant barrier as most efficiency improving technology will rely on real time information. *Value Proposition:* Adoption of efficiency boosting technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Will require data transfer between growers and processors. Trust issues could be a constraint.
Grape harvest	*Connectivity:* Improved connectivity is essential for most in field monitoring leading to supply chain efficiencies. *Data/ Decision Support:* Not a significant barrier as most efficiency improving technology will rely on real-time information. *Value Proposition:* Adoption of efficiency boosting technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Will require data transfer between growers and processors. Trust issues could be a constraint.

Forest and Wood Products

Industry Overview

The Australian forestry and wood products industry is an important contributor to the Australian economy. In 2015–16 the volume and value of logs harvested in Australia were estimated to have reached record levels, coinciding with strong domestic and international demand conditions. Despite this, the industry is facing major challenges that threaten the profitability and long-term sustainability of the industry. These include high cost of labour and regulation, which are affecting the competitiveness of the manufacturing sector and the supply of wood.

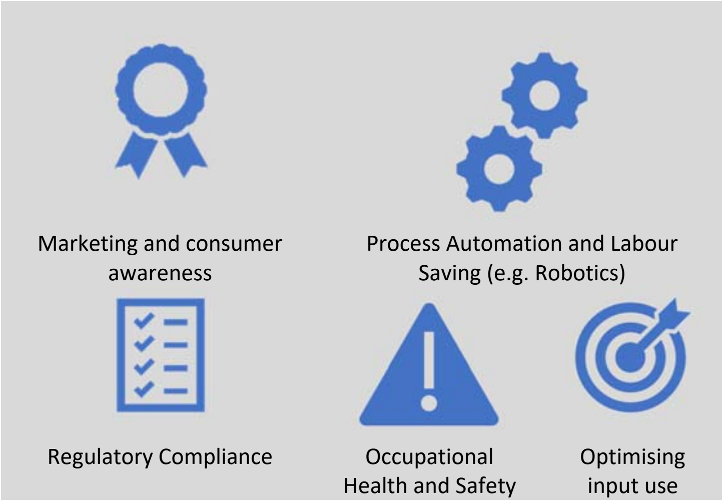
The Australian forest products sector produces a range of products for the domestic and international market. This includes solid wood used for construction, wood-based panels, engineered wood products, and paper and paperboard products. Each Australian was estimated to have consumed the equivalent of 0.81 cubic metres of logs in 2012–13 (Davey and Dunn, 2014). New technologies are opening up opportunities for new uses of forest and wood products including the use of cellulose in a range of products from medicines, industrial chemicals, biofuels and bioplastics.

Domestic and global demand is likely to grow as populations increase. While increased consumption of forest products over the long term presents opportunities, the Australian sector is competing against increasing volumes of imported and substitute products. The competitiveness of Australian manufactured products is largely determined by their cost in comparison with imported products. This issue is heavily influenced by exchange rates and major manufacturing costs such as infrastructure, energy, transport and labour.

The future of this sector depends on its ability to successfully compete against international forest products in domestic and export markets and to harness opportunities to better utilise wood resources for higher value products.

The industry is a major source of employment in many regional areas. Australia's total employment in the forest products sector (forestry, wood, pulp and paper manufacturing) in 2013–14 was 70 500 (Davey and Dunn, 2014). The industry is currently facing considerable challenges in ensuring the sustainability of processing the sector (e.g. issues surrounding the closure of the Heywood timber mill in Victoria).

Key Drivers of Decision Agriculture



The Australian forest and wood product industry has experienced overall growth in the value and volume of products harvested in recent years. There are, however, some major challenges for the industry including high costs of regulation and labour, which are affecting the competitiveness and sustainability of the industry.

Digital technologies have the potential to increase productivity across the wood and forest product supply chain. This includes the use of satellite technologies and remote sensing to monitor and manage forest resources, the use of automation and robotics in harvesting and manufacturing activities, and the use of radio frequency identification (RFID) and tracking technologies to improve the efficiency of the supply chain.

The Australian forestry industry's current investment priorities include: increasing the use of timber and wood construction systems in multi-residential and commercial buildings; maximizing product yields and values from current forest resources; improving wood quality and yield; and, tools for forest management.

As a small player in the global forestry industry there are opportunities for Australia to adopt technologies that are currently used in the larger North American and European forestry industries. This particularly includes harvesting equipment, milling technologies, and software systems.

There are a range of applications for digital technologies and big data analytics in the forestry and wood products industry.

Potential applications of digital technologies include:

- New domestic and export business, including the development of new wood products e.g. cellulose products for the cosmetics industry.
- The use of RFID and tracking technologies to improve the traceability of wood products.
- Improving the attractiveness of the sector to potential high-skilled workers.

- Tools that could assist with the valuation of forest resources for different users (e.g. commercial forestry, environmental value, and recreation/social value). This could support better public decision-making about forest resources, including social, environmental and economic uses.
- The use of satellite imagery to monitor wood supply and meet environmental regulations.
- The use of high-density 3D laser scanning of trees to quickly and accurately assess aboveground biomass components of single trees. This technology could also be used to ensure effective utilisation of forest resources. For example, it could help the assessment of tree quality at harvesting sites, including stem curve and diameter distribution.
- Improved ecological monitoring (carbon, water, biodiversity) to meet environmental regulations and maintain the industry's 'social licence to operate'.

There are arguably two areas that represent both the greatest challenges currently facing the Australian forest and wood product industry, and the greatest opportunities for digital technology:

- Building an innovative, competitive and profitable manufacturing industry.
- Maintaining the industry's 'social licence to operate.

Sustaining an innovative, competitive and profitable manufacturing industry

New investment in wood resources and processing facilities is vital if the sector is to meet future demand and remain internationally competitive. Since 2006–07, investment in new plantations in Australia has decreased substantially. In addition, the total number of sawmills in Australia declined in this period, from 610 in 2006–07 to 281 in 2012–13 (Gavran et al. 2014). There are a number of factors that influence the ability of the sector to attract private investment in wood resources, new processing facilities, or changes in existing processing capacity or product lines. These include sufficient and secure access to wood volumes at a competitive price, appropriate infrastructure to assist competitiveness, opportunities that align processing scale with the resource and market, access to technology and a well-trained and skilled labour force (Gavran et al. 2014).

Finding uses and markets that allow for greater utilisation of harvested logs is a key challenge for the Australian forest products sector. In many regions, the viability of forest harvesting and wood processing is influenced by the need for reliable markets for wood residues. Wood residues include harvested logs not suitable for processing into sawn wood or veneer products and offcuts, chips and sawdust generated from wood processing operations. Emerging forest products could increase demand for wood and help overcome some of the resource utilisation and value-adding challenges in Australia. For example, finding alternative markets for hardwood residues is a key issue for those Australian wood processors and forest managers that are heavily reliant on the woodchip export market for the residues generated from their operations. These emerging products and uses include using wood and wood fibre to produce new building systems, transportation fuels, biochemicals, biomaterials, electricity and heat. Integrating these emerging products with established industries in the sector could enhance the product mix manufactured by the sector and improve the profitability and resilience of the sector.

The labour and skill requirements of the sector are very broad, from heavy vehicle drivers, qualified foresters and timber engineers, specialists in wood harvesting and processing, manufacturing workers to market development analysts and scientific researchers. A key challenge for the sector is identifying current and future skill development and training requirements and attracting and developing new recruits for all levels of employment across the sector.

Maintaining the industry's 'social licence to operate'

One of the fundamental challenges and opportunities for the industry is meeting community expectations about the sustainability of its operation. Harvesting operations are governed by stringent codes of practice and management prescriptions that take account of social and environmental considerations. Australia has an internationally recognised record of sustainable forest management, which is supported by Commonwealth and state policies and legislation. State forest management agencies and private sector organisations are certified under voluntary standards, such as the Australian Forest Certification Scheme (AFCS) and the Forest Stewardship Council (FSC). Despite this, anti-forestry campaigns have affected some trade in international and domestic markets. A positive and consistent industry-led narrative, supported by government, is needed to inform local and international consumers about the sustainability of Australian forest produce.

Recognition of the environmental credentials of forest products provides further opportunity for greater use of wood in construction projects. These credentials include: wood sequesters carbon, it is a renewable resource and that it generally produces lower emissions during production than many other construction materials. There is recognition of the environmental benefits of using wood in construction under rating systems that evaluate the environmental design and construction of buildings. Some local, state and national governments are also promoting or mandating the use of wood in the construction of public buildings.

The potential economic benefits of decision agriculture for the forest and wood products industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the forestry and wood industry.

Table A2.17: The potential economic impacts of decision agriculture on the Australian forestry industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Site selection	Environmental data at more granular scale used for better site selection for planting to avoid frost and other impacts on tree survival and growth rate.	Overall productivity improvement of 4% [Modelled as 'Forestry']	98.07	98.73
Disease and pest control	Remote and proximal imagery and other sensed data used to detect pest and disease issues and treat before economic harm results.	Overall productivity improvement of 5% [Modelled as 'Forestry']	122.59	123.41
Pruning and thinning	Aggregated multi-site data used to inform pruning and thinning decisions for higher yield of quality timber.	Overall productivity improvement of 4% [Modelled as 'Forestry']	98.07	98.73
Labour saving	Automation and robotics allows reduction in labour use. Electronic record keeping embedded in operations (reduced cost of regulatory compliance).	Labour reduced by 10% [Modelled as 'Forestry']	126.64	149.76

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Site selection	*Connectivity:* Current connectivity is largely sufficient to meet requirements. Site selection decisions can be made remotely (e.g. in offices). *Data/ Decision Support:* Heavily dependent on integrating multiple public and private data sets. *Value Proposition:* Potential benefits may be constrained by long production cycle (e.g. 25-year planning horizons. *Legal/ Trust issues:* Not likely to be a significant issue.
Disease and pest control	*Connectivity:* Improvements in connectivity infrastructure in remote forest areas will be required (including satellite monitoring). *Data/ Decision Support:* Will require integration of multiple data sets. *Value Proposition:* The value proposition is widely recognised given the significant economic impacts of pest and disease outbreaks. *Legal/ Trust issues:* Not likely to be a significant issue.
Pruning and thinning	*Connectivity:* Improvements in connectivity infrastructure in remote forest areas will be required. *Data/ Decision Support:* Requires integrating multiple real-time and historical datasets. *Value Proposition:* The benefits are high, particularly for some premium timber varieties. However, the infrequency of pruning decisions may limit full realisation of benefits. *Legal/ Trust issues:* Not likely to be a significant issue.
Labour saving	*Connectivity:* Likely to be a significant barrier given many forestry regions have limited connectivity. Many labour saving technologies require strong connectivity. *Data/ Decision Support:* Many labour saving technologies require the integration of multiple data sets. Likely to be constrained by limitations in data analytics capacity. *Value Proposition:* Labour is a major cost of production. The value proposition is likely to be strong for labour saving technologies. *Legal/ Trust issues:* Not likely to be a significant issue.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Processing logs for timber	Data captured on logs during felling and handling process used to program processing operations so that maximum amount of useable timber is extracted from logs. Data captured in harvesting and processing leads to more efficient kiln processes for drying timber as well as opportunities to target higher value markets through more targeted processing of logs.	Overall productivity improvement of 30% [Modelled as 'Wood and paper products and printing']	4,102.81	5,571.03
Labour saving	Increased adoption of robotics and automation in timber/ wood products processing reduces labour costs.	Labour costs reduced by 20% [Modelled as 'Wood and paper products and printing']	962.87	1,442.84
		Total	**5.511.05**	**7,484.49**

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Processing logs for timber	*Connectivity:* Connectivity largely sufficient at processing facilities but there are limitations in some forest areas. *Data/ Decision Support:* Relies on integrating multiple data sets. Improvements in data analytics capacity will be required. *Value Proposition:* Optimising timber quality and reducing product wastage is a major driver of profitability. *Legal/ Trust issues:* Not likely to be a significant constraint.
Labour saving	*Connectivity:* Current connectivity is largely sufficient to meet requirements. *Data/ Decision Support:* Requires sophisticated data analytics technologies e.g. calibrating robotic saws etc. *Value Proposition:* Labour is a major cost to timber/ wood processing. The value proposition is likely to be strong for labour saving technologies. *Legal/ Trust issues:* Not likely to be a significant constraint.

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Large industry with relatively few players (and increasing consolidation).
- Adoption of forest (and plantation) management tools limited by long-term production system (e.g. 25-year cycles).
- Potential spillover of technology from New Zealand, North America, and Scandinavia (including remote monitoring).
- High potential for technology development in the timber processing sector (driven by need to reduce labour costs and wastage of wood).

Livestock Exports

Sector Overview

Australia has a long history as a major exporter of live sheep, live beef cattle and in more recent times live dairy cattle and goats. The live animal export trade has been growing in importance for Australian livestock producers, as Asian and Middle Eastern consumers have transitioned from carbohydrate-based diets to protein-based diets and demand for meat and dairy products in these regions has expanded. For cultural and logistical reasons, the preference in many of these markets is for imports of livestock that are suitable for fattening and subsequent slaughter in the destination market, or which can be slaughtered close to the final market due to a lack of cold chain logistics (AFI, 2016a). Equally important from an Australian perspective is that livestock exports provide alternative market outlets and a greater range of marketing options which assists Australian livestock producers to better manage risk.

Live cattle exports from Australia commenced in the 1960s, although export number remained relatively modest until the mid-1990s when demand for red meat began to grow in Asian markets. Political and other developments both in Australia and in destination markets have resulted in occasional large fluctuations in annual export numbers, most recently in 2011 when the Australian Government suspended the export of live cattle to Indonesia – which was then a major market. Live cattle exports have recovered to approximately 1.3 Million in 2015, valued at approximately $A 1.5 Billion (AFI, 2016a).

Live sheep exports grew rapidly during the 1970s, as a result of strong sheepmeat demand emanating from Middle Eastern nations, and the relatively large sheep flock present in Australia, especially during the 1980s. The trade was interrupted by the turmoil associated with the cessation of the Wool Reserve Price Scheme in 1991 and associated initiatives such as the flock reduction scheme which resulted in the culling of 10 Million sheep (AFI, 2016a). It recovered somewhat during the mid-to-late 1990s, but the continuing decline in the size of the Australian sheep flock in combination with a switch by many woolgrowers to prime lamb production reduced the supply of merino wethers suitable for the live export trade, and annual sheep exports have been steadily declining since that time. In 2015, Australia exported 1.96 Million live sheep, valued at $246 Million (AFI, 2016a).

The live export sector is fundamentally a logistics operation with the added requirement of ensuring animal welfare standards throughout the process. The sector will benefit from decision agriculture technologies that are able to aid in tracking and monitoring of logistics movements and in animal health monitoring.

Key Drivers of Decision Agriculture

The Australian livestock export industry has undergone significant transformation over the past five or so years in response to growing regulatory pressure to demonstrate animal welfare across the supply chain.

The primary commercial objectives for livestock exporters are minimising input costs and livestock losses, maximising their buy/sell margin, and complying with government regulatory requirements which enable them to operate. Animal health related measures of morbidity and mortality are important performance indicators for exporters.

The major cost elements impacting exporters' productivity include the capital cost of livestock, quarantine and transport/ shipping costs, regulatory compliance and associated labour and administration costs.

The key interconnected areas where decision agriculture has the potential to have the greatest impact are:

- Reducing the costs of regulatory compliance.
- Improved animal health, welfare and performance.
- Procurement, logistics, and supply chain efficiencies.
- Maintaining market access and the industry's 'social licence to operate'.

Other impacts* on the livestock export industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Market access and maintenance negotiation	Digital traceability and provenance systems providing confidence for end users in safety and quality of Australian livestock. Maintaining and developing new high value markets for Australian livestock.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Maintenance of markets and prevention of spread of pests.	*Connectivity:* Real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. Large barrier for live export industry. *Data/ Decision Support:* Not likely to be an impediment as relying on real time data. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Australia is most technologically advanced player in the global market.
- Limited potential for international technology spillover.
- Technology spillover likely to occur from associated industries (e.g. animal health and monitoring technologies from the beef feedlot sector, and supply chain management technologies from the transport industry).
- Adoption of new technologies likely to be driven by cost (i.e. need to remain competitive with low-cost exporters such as Brazil) and regulatory/ compliance (i.e. improving the efficiency of meeting Export Supply Chain Assurance Scheme requirements and global assurance program requirements).

Table A2.18: The potential economic benefits of decision agriculture for the livestock export industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Transport and logistics	Digital technologies improve supply management (livestock procurement) and improve the efficiency of livestock transport/ logistics.	Transport costs reduced by 5%	15.6	13.9
Animal health and welfare monitoring	Current: Reliance on highly trained stockpersons and veterinarians. Difficulties in early identification of animal health issues (e.g. shy feeders). Remote sensing and decision-support tools are used to help monitor changes in animal behaviour and guide early intervention of health issues.	Overall productivity increased by 2%	28.1	82.6
Regulatory compliance	Costly (labour intensive), manual, and inefficient regulatory compliance.	Overall productivity increased by 2%	28.1	82.6
		Total	**71.7**	**179.0**

Source: AFI and LiveCorp 2017

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Transport and logistics	*Connectivity:* Investments in technologies that operate in low-connectivity environments will be required to realise potential benefits. Connectivity is currently a substantial barrier. *Data/ Decision Support:* Not perceived to be a barrier as will be relying on real-time data capture rather than analysis of historical datasets. *Value Proposition:* Adoption likely to occur if direct costs reduced e.g. transport. *Legal/ Trust issues:* Potential barrier as data will need to be shared between different components of transport logistics chain.
Animal health and welfare monitoring	*Connectivity:* Investments in technologies that operate in low-connectivity environments will be required to realise potential benefits. Connectivity is currently a substantial barrier. *Data/ Decision Support:* Not perceived to be a barrier as will be relying on real-time data capture rather than analysis of historical datasets. *Value Proposition:* Mortality and morbidity a significant cost so value proposition high in reducing these. *Legal/ Trust issues:* Potential barrier as data will need to be shared between different components of transport logistics chain.
Regulatory compliance	*Connectivity:* Investments in technologies that operate in low-connectivity environments will be required to realise potential benefits. Connectivity is currently a substantial barrier. *Data/ Decision Support:* Access to government databases required, likely to be a barrier until more consistent data standards and accessibility. *Value Proposition:* There is a large amount of regulation in the live export industry. Relieving regulatory burdens through decision agriculture platforms will have a large value proposition. *Legal/ Trust issues:* Compliance based so unlikely to be a barrier.

Red Meat Processing

Sector Overview

Red meat processing is now Australia's second largest manufacturing sector. With processing facilities located around the country, the red meat processing sector contributes significantly to the national economy in terms of employment, household income and industry value-added (AMPC 2016).

The main stages of meat processing are:

- Preparation for slaughter
- Slaughter
- Hide/skin removal
- Removal of internal organs
- Trimming and carcase washing
- Weighing and grading
- Chilling
- Boning
- Packaging
- Freezing or cold storage
- Plant cleaning.

In addition to these generic processes, some establishments may also undertake other activities, such as rendering, hide and skin processing, and blood processing.

The industry faces a number of challenges including labour and skill shortages, the high cost of production relative to global competitors, and an increasing regulatory burden. At an operational level, Australia's red meat processing costs are the highest in the world. Australia's processing costs are 1.5 times higher than NZ, 2.4 times higher than the US, 3.0 times higher than Brazil, and up to 20 times higher than in Indonesia (AMPC 2016). The main reasons for the lower relative costs of processing in other countries are lower labour costs, greater economies of scale, and high levels of capital investment that enable cost-effective use of new technologies. As a consequence, it is difficult for the Australian industry to compete on purely a cost basis, requiring the industry to compete based on differentiation. Australia’s traditional competitive advantages lie in its superior product quality, integrity, and traceability.

For the Australian red meat processing industry to remain globally competitive with lower cost operators (such as Brazil and the US) the industry must continue to innovate in developing tools, products, processes and manufacturing technologies that deliver meat processing efficiencies and add value to meat products.

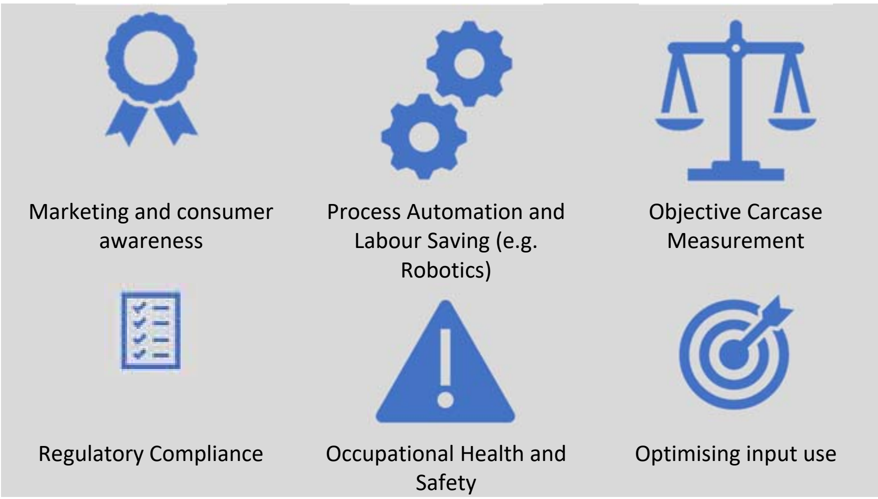
In the past few decades there has been increasing consolidation in the red meat processing sector. This has been driven by the need for processors to have economies of scale to remain profitable. There are two major players in the beef processing sector, JBS Australia and Teys Australia, which operate multiple processing facilities across the eastern states. Following these two large firms are several medium scale operators, including NH Foods, Northern Cooperative Meat Company, Thomas Foods International, Bindaree Beef and Australian Country Choice, and a range of smaller processors. The ACCC estimates that Australia's five largest processors account for around 54 per cent of total slaughter capacity, making the sector relatively concentrated (albeit less so than the United States) (ACCC, 2016). The table below outlines the number of Australian (red meat) livestock slaughtered in 2015–16.

Table A2.19: Australian livestock slaughtered 2015–16.

Cattle (excluding calves)	8,189,000
Sheep	8,127,000
Lamb	23,131,000
Goat	2,213,265

Source: ABS 2016 and Department of Agriculture and Water Resources 2016.

Key Drivers of Decision Agriculture



Digital technologies have the potential to directly address some of the key challenges facing Australian red meat processors, including high labour and regulatory/ compliance costs. At the same time, digital technologies could facilitate new opportunities such as OCM, which could lead to benefits such as improved carcase utilisation and improved product quality.

The key drivers for innovation are technologies that increase productivity and reduce cost of processing, and that enhance product quality, carcase yield and value while also meeting compliance requirements (e.g. environmental impacts). For new technologies to be adopted there must be a clear value proposition to processors:

> *"With increasing pressure on industry in terms of input costs, investments in technology will only be considered valuable if they address delivery of the product to the marketplace in a manner that adds value to the business."* (AMPC Strategic Plan 2013)

Traceability technologies such as RFID (radio frequency identification) are likely to act as the foundational technology for a range of technological developments. RFID enabled technology gives processors the means of sophisticated data collection to better understand market behaviour, provide feedback to producers, and benchmark performance (AMPC AOP 2015–16). As datasets grow and are aggregated there will new opportunities for data analytics to identify areas to improve efficiency across the supply chain.

Changes to labour use and improvements in workplace health and safety

Digital technologies are likely to shape the labour and skill requirements of the red meat processing industry. They are also likely to improve working conditions and reduce work-related injuries and illnesses. Currently the industry is constrained by shortages of skilled and (relatively) unskilled workers. Automation and robotics could lead to improvements in workplace health and safety. For example, helping eliminate the risk of operator strain or trauma from traditional techniques such as carcase splitting. Attracting skilled labour is one of the greatest challenges for the red meat processing industry. Skilled labour shortages lead to lower productivity or higher production costs (e.g. overtime payments etc.). Developments in automation and robotics may displace some jobs (e.g. in labour intensive jobs like carcase splitting) while also creating new job opportunities (e.g. software engineers).

Operational efficiencies in meat processing

There are likely to be major improvements in processing efficiency through the uptake of new technologies, particularly in robotics and automation. This includes improvements in materials handling, slaughter, boning and cutting activities.

These technologies can provide improved accuracy and repeatability of automated meat processing activities than systems controlled by hand. For example, currently most beef carcase splitting is performed manually by operators using industrial bandsaws which present significant OH&S risks.

There is a requirement for a high level of accuracy to maximise yield and these tasks can't be performed by unskilled operators. The use of robotic beef splitters which utilise specially designed cutting tools integrated to a robot system can ensure quality assurance and product specifications are met, while reducing the risks of workplace health and safety incidents.

Product quality improvements

Developments in areas such as OCM could lead to improvements in product quality and food safety. This includes reducing wastage of meat products (e.g. increased yield) through more accurate cutting. OCM will also allow processors to sort meat products according to tighter product specifications and more effectively match products with customer/ market requirements.

Importantly, OCM feedback can be used to inform on farm decision-making, particularly in the areas of breeding (genetics) and feeding. For example, it could help identify superior bloodlines for commercially valuable traits such as intramuscular fat and lean meat yield. It could also help producers develop feeding strategies that ensure market specifications (e.g. fat depth and carcass weight) are met.

Reduced regulatory costs

The red meat industry is one of the most highly regulated industries in the Australian economy. There are a range of regulatory issues that processors must meet in order to remain operational, all of which represent a cost to the business. Regulatory issues include:

- Agricultural regulation, including: biosecurity; land use and environmental impact; chemical use; animal welfare standards; and livestock certification and identification.
- Food and meat processing regulations e.g. food safety.
- Trade regulations and quotas.
- Emissions regulations.
- Environmental regulations e.g. water use.
- Employment policies and minimum wages.
- Competition and capital related regulations that impact the ability of merger and acquisition activity in the industry or capital investment.

Digital technologies have the potential to automate the collection and reporting of data, which could reduce the costs of regulation.

Improving value chain relationships through information flow

There are significant opportunities for digital technologies to be used to improve the relationships between businesses across the supply chain, particularly through the sharing of information. The relationship between red meat producers and processors is currently characterized by a lack of communication and trust. This was reflected in sentiments shared in the ACCC's 2016 market study into the beef and cattle industry. The industry-wide use of objective carcase measurement, which will rely on digital technologies, could improve the feedback of valuable information and lead to new payment systems based on objective meat quality measurements.

The potential economic benefits of decision agriculture for the red meat processing industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the red meat processing sector.

Table A2.20: The potential economic impacts of decision agriculture on the Australian red meat processing industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Livestock sourcing and assessment	[Current: Live animals are visually assessed/ appraised by buyers.] Scanning technologies are able to accurately identify higher value animals (lean meat yield and marble score) and more consistent lines of animals. This reduces wastage (i.e. non-compliant carcases) and allows for improvement in processing efficiency/ higher throughput.	Overall productivity increased by 2%	280.2	326.9
Processing labour efficiencies (including slaughtering, boning and cutting)	[Current: Highly trained ($) staff perform dangerous tasks (e.g carcase splitting) with a reasonable level of inaccuracy (i.e. some wastage of product)] Scanning technologies and robotic cutting technologies are able to precisely cut carcases and specific cuts.	Labour costs reduced by 30%	400.4	477.4
Processing efficiencies/ carcase utilisation	Reduced wastage of meat products (increased carcase utilisation) from more precise boning/ cutting	Overall productivity increased by 3%	420.3	490.3
Red meat marketing	[Current: Limited feedback/ information on product quality across the supply chain] Processors provide retailers with more information about product quality.	Overall productivity increased by 5%	700.5	817.3
Regulatory compliance	[Current: Costly (labour intensive), manual, and inefficient regulatory compliance] Streamline/ automate/ digitise data collection and reporting to meet compliance requirements	Overall productivity increased by 2%	280.2	326.9
		Total	**2081.5**	**2438.8**

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Livestock sourcing and assessment	*Connectivity:* Current connectivity is largely sufficient to meet requirements. *Data/ Decision Support:* There are challenges associated with layering/ analysing multiple data sets (e.g. a lack of industry data standards). Technologies are in early stages of development. *Value Proposition:* The potential benefits and value proposition are well understood. Industry is investing in live animal scanning technologies to measure eating quality etc. These technologies are currently under development or at 'proof of concept' stage. *Legal/ Trust issues:* There are some concerns about data sharing and ownership e.g. producers concerned that data shared on animal performance could be used to justify penalties and discounting of meat. At the same time, there is recognition that this technology could improve transparency and data flow across the supply chain.
Processing labour efficiencies (including slaughtering, boning and cutting)	*Connectivity:* Current connectivity is largely sufficient to meet requirements. *Data/ Decision Support:* Requires ongoing investment in data management and decision support tools e.g. calibrating technology to ensure accuracy. *Value Proposition:* The benefits of robotics technologies are well understood by processors, including labour savings and improved workplace O.H.& S. *Legal/ Trust issues:* Not likely to impact adoption of technology. However, there may be a kickback from workers and unions if technology continues to replace jobs.
Processing efficiencies/ carcase utilisation	*Connectivity:* Current connectivity is largely sufficient to meet requirements. *Data/ Decision Support:* Requires ongoing investment in data management and decision support tools e.g. calibrating technology to ensure accuracy. *Value Proposition:* The value proposition is well understood – improving carcase utilisation could lead to major savings. *Legal/ Trust issues:* Not significant.
Red meat marketing	*Connectivity:* Current technology needs are largely sufficient to meet requirements. Additional investments may be needed in some supply chains. *Data/ Decision Support:* Data-intensive process. Will require investments in tools that automate data collection and transfer. *Value Proposition:* Commercial pull-through (e.g. price premiums) are required to justify investments in technology. *Legal/ Trust issues:* This technology could improve traceability and validate provenance claims (i.e. address legal issues of false product labelling).
Regulatory compliance	*Connectivity:* Current technology needs are largely sufficient to meet requirements. *Data/ Decision Support:* Will require investments in tools that automate data collection and transfer. The adoption of industry-wide standards (e.g. data formats) could help reduce regulatory burden. *Value Proposition:* Systems are likely to be successful if they reduce costs and regulatory burden on processors. *Legal/ Trust issues:* The integrity of systems and their supporting data is critical.

Other impacts* on the red meat processing industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Market access and maintenance negotiation	Digital traceability and provenance systems providing confidence for end users in safety and quality of Australian red meat. Maintaining and developing new high value markets for Australian red meat.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems not relying on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance-based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Maintenance of markets and prevention of spread of pests.	*Connectivity:* Real-time system for biosecurity monitoring requires extensive data flow across production areas and throughout value chains. *Data/ Decision Support:* Not likely to be an impediment as relying on real time data. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- Large market for new technologies (likely to attract new business models and products/ services).
- High level of digital maturity in industry.
- Australia's need to remain internationally competitive will drive cost-reducing initiatives (e.g. automation and robotics) and product quality/ marketing initiatives (e.g. provenance and eating quality assurance).

Fisheries and Aquaculture

Sector Overview

Australia has a diverse fisheries and aquaculture industry, which stretches from the tropics to Antarctica. In addition, it also includes some freshwater fishing and aquaculture, which operate on land, rivers, and estuaries across a range of regions and climates. There are over 600 species targeted and produced targeted, with a range spread across fisheries and aquaculture. Management practices vary according to species. This ranges from short fishing trips to longer voyages out to fishing grounds at the boundaries of Australia's fishing zone.

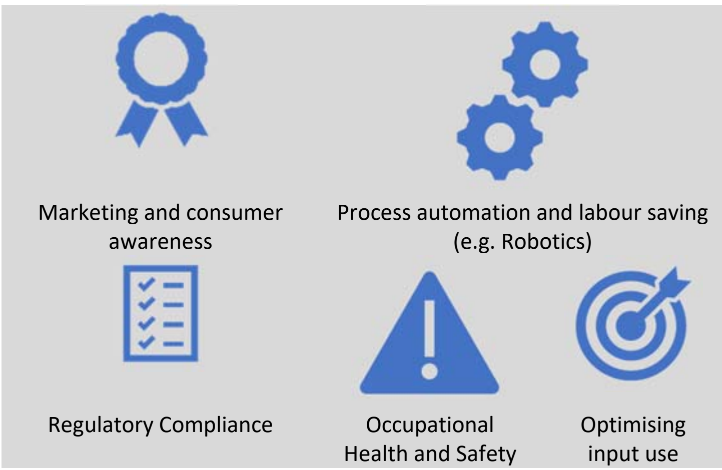
Australia has the third largest marine territory in the world. However, due to a lack of nutrient-rich currents, Australia ranks only 52nd in the world in terms of the volume of fish landed (Savage, 2016). Main products in the fisheries (wild caught) sector include finfish, rock lobster, prawns, abalone and scallops. Main products in the aquaculture sector include: salmonids, prawns, barramundi, and abalone.

There has been a decline in the number of fishing enterprises due to increasing operating costs and government regulation. High commercial licence fees limit the number of new entrants into the industry. In recent years, corporate aquaculture businesses (e.g. Tassal) have grown significantly. There is a higher degree of vertical integration in the aquaculture sector than the fishing sector, which has allowed it to grow relatively quickly.

In the past fifteen years, there have been two major shifts in Australia's fisheries industry:

1. Australia became a net importer of seafood in 2007–08 (in value terms). Since then the gap between the value of imports and exports has widened. This is due to a large increase in imports and small decrease in exports.
2. A contraction in wild caught fisheries production and a massive expansion of the aquaculture sector. Most of this growth can be attributed to the farmed salmonids.

Key Drivers of Decision Agriculture



The key drivers of digital technology in the fisheries industry relate to productivity and profitability and resource access. Technology has the potential to improve the efficiency of boat operations and harvesting methods, while potentially increasing yields and allowing better use of underutilised species. Australia's marine and freshwater resources are multi-user environments. There are competing claims for the resource between fishing and aquaculture sectors, as well as other users such as the oil and gas, and community groups wanting greater protection of resources. Digital technologies have the potential to reduce the regulatory and compliance costs associated with fishing and aquaculture, while also helping the industry to demonstrate its sustainability (i.e. social licence to operate).

The potential economic benefits of decision agriculture for the fisheries and aquaculture industry

The following section describes the 'shocks' that were identified as potential areas in which decision agriculture could impact productivity in the fisheries and aquaculture industry.

Other impacts* on the fisheries industry

Practice/ Decision	Change with decision agriculture	Effect of current constraints on likely realisation of benefits
Market access and maintenance negotiation	Digital traceability and provenance systems providing confidence for end users in safety and quality of Australian seafood. Maintaining and developing new high value markets for Australian seafood.	*Connectivity:* Improvements in connectivity will be vital as traceability systems require data flow throughout the value chain from producer to consumer. *Data/ Decision Support:* Not likely to be an impediment as traceability systems do not rely on historical data and analysis. *Value Proposition:* Traceability and provenance provide the ability to build and maintain markets. Value proposition understood to be high. *Legal/ Trust Issues:* Traceability likely to be compliance-based so trust issues not perceived to be significant barrier. Provenance systems more likely to be voluntary and trust in sharing data may be an impediment.
Biosecurity monitoring	Industry-wide digital platforms (manual and automated) for pest presence and movement to monitor and manage biosecurity issues. Maintenance of markets and prevention of spread of pests.	*Connectivity:* Real-time systems for biosecurity monitoring require extensive data flow across production areas and throughout value chains. *Data/ Decision Support:* Not likely to be an impediment as relying on real time data. *Value Proposition:* Biosecurity breaches can shut down industries. Value proposition extremely high for implementation of effective system. Not likely to be a barrier. *Legal/ Trust Issues:* Likely to be compliance based so trust issues not perceived to be significant barrier.

*not assessed during the economic modelling

Implications for business and service delivery models

Based on insight from the structural analysis of the sector and results from the economic modelling the following factors are likely to influence the development of new business and service delivery models:

- High potential for advanced data analytics given high level of historical catch data (e.g. predictive analytics – fish stock mapping and modelling).
- Fundamental drivers of technology and practice change will be improving catch efficiency, reducing labour costs, operational efficiencies (e.g. reducing boat costs), and regulatory pressures.
- Governments are likely to continue playing a major role in influencing management decisions given the highly regulated nature of the sector.
- Regulatory pressures are likely to increase (e.g. sustainability of fishing, environmental impact of aquaculture, competition for marine resources for economic and environmental uses etc.).
- Pressure from cheap frozen seafood imports is likely to impact the competitiveness of the wild-caught sector.
- There is potential for a two-speed industry e.g. continued growth of aquaculture sector and continued contraction of wild-caught fisheries sector.

Table A2.21: The potential economic impacts of decision agriculture on the Australian fisheries industry.

Practice/ Decision	Change with decision agriculture	Magnitude of impact	Impact on GVP ($m)	Impact on GDP ($m)
Catching fish more efficiently	By having access to real-time data on fish stocks and locations, fishing boats can spend less time catching fish by fishing in locations where the maximum allowable yield is met more quickly. Efficiency savings in boat operations.	Overall productivity improvement of 30%	708.67	623.89
Operating boats at sea	Data on winds, currents etc provided in real-time to help with navigation and operation to plot the most efficient course to fishing grounds or ports. Efficiency savings in boat operations.	Overall productivity improvement of 5%	118.11	103.98
Labour saving	Automation and robotics allows reduction in labour use.	Labour costs reduced by 10%	101.52	126.94
		Total	**928.30**	**854.81**

Source: AFI and FRDC 2017.

Practice/ Decision	Effect of current constraints on likely realisation of benefits
Catching fish allowed under quota	*Connectivity:* Unique connectivity constraints with off shore activity requiring satellite communications. *Data/ Decision Support:* Critically dependent on accumulation and sharing of multiple sets of data. Significant technical and industry structural constraints. *Value Proposition:* Very significant productivity gains to be made through increasing efficiency of fishing operations. *Legal/ Trust issues:* Significant industry structural and regulatory issues around ability and willingness to accumulate and share data.
Operating boats at sea	*Connectivity:* Unique connectivity constraints with off shore activity requiring satellite communications. *Data/ Decision Support:* Critically dependent on accumulation and sharing of multiple sets of data. Significant technical and industry structural constraints. *Value Proposition:* Very significant productivity gains to be made through increasing efficiency of fishing operations. *Legal/ Trust issues:* Significant industry structural and regulatory issues around ability and willingness to accumulate and share data.
Labour saving	*Connectivity:* Mostly involving on-board or processing based activity without need to communicate beyond those stages. Not perceived to be significant constraint. *Data/ Decision Support:* Doesn't require multiple data sets. Not perceived to be a constraint. *Value Proposition:* Adoption of labour saving technologies is driven by perceived cost-benefits, and impacted by connectivity and data/ decision support. *Legal/ Trust issues:* Autonomous applications have legal and trust issues that are yet to be resolved. Does not necessarily require sharing of data throughout value chain.

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Appendix 3. Review of Decision Agriculture Products

The following tables provide a list of decision agriculture products available in Australia. Although the list is comprehensive it is not exhaustive with new products emerging almost on a daily basis.

The products have been categorised to provide some reference to themes covered in this report. The business model used for development has been listed if available as well as the scope of the product and connectivity requirements for its use.

Business model categories; G = Government, P = Partnership, RDC = research and development corporation, C = corporation, I = International (developed by internationally based company with product features available in Australia), S = Start-up (listed as start-up based on information prescribed by individual business website)

Scope: N = Narrow, B = Broad

Crop Management: Multi-Use

Product	Description/Features	Business Model	Scope	Connectivity
Hay vs. Grain calculator http://agriculture.vic.gov.au/agriculture/grains-and-other-crops/grains-calculators	• Online calculator • Calculates gross margin of grain and hay production • Assists in deciding whether to leave crop for harvest or cut for hay	G (Agriculture Victoria)	N	Connection required (online)
MyCrop https://www.agric.wa.gov.au/mycrop	• Collection of apps • Individual app for each crop type: Pulses, Wheat, Canola, Oats, Barley • Identify crop problems and production constraints • Provides information on solutions and management strategies •	G (DAFWA)	B	Offline use (after download)

Product	Description/Features	Business Model	Scope	Connectivity
ARM Tools - Climate ARM - FallowARM - CropARM - Nitrogen ARM http://www.armonline.com.au/#/ Queensland Government	• Collection of agricultural risk management tools • Uses modelling and climatic forecasts to simulate effects of crop inputs (crop type and fertiliser) and existing resources (soil/water) on yield and economics outcomes	G (DAF QLD)	B	Connection required (online)
NVT Disease and Yield App http://www.nvtonline.com.au/ GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION	• Varieties include: wheat, barley, canola, chickpea, faba bean, field pea, lentil, lupin, oat and triticale Disease app – quick access to current disease resistance ratings, disease information and detailed disease image library - Compare resistance ratings and symptoms - Up to date/live feed for the Australian National Variety Trials database Yield app – access and interpret data from the GRDC funded NVT program - Provides detailed analysis of the findings of the program - Aggregates mean yields and compares the variety performances in easy to read table/graph • Users having access to live data with automatic updates from NVT database	RDC (GRDC) ruralR&D CORPORATIONS	N	Connection required (receive updates from NVT database)

Product	Description/Features	Business Model	Scope	Connectivity
CropPro http://www.croppro.com.au/	• Diagnostic and economic tools for identifying causes of wheat and canola crop problems • Look at potential impacts and management options	P (GRDC/Department of Environment and Primary Industries Victoria)	B	Connection required (online)
LiveFarmer https://www.livefarmer.com/lfsite/index.html	• Suitable for: wheat, vegetables, fruits, orchards, vineyards • Online farm management and quality assurance application • Collection of field data and report generation • Real time data capturing system that utilises phone network, all data updated in records instantly Crop manager – define crop, break down tasks and organise operation Pesticide application record – store pesticide records in system and print reports Vendor module – keep track of people/places interacting with business Inventory tool – monitor supplies • Equipment manager – equipment database to keep records on servicing and maintenance	C (Livefarmer)	B	Connection required (download, sync/update data)

Product	Description/Features	Business Model	Scope	Connectivity
IGrain https://www.igrain.com.au/	• Online platform for grain trade • Access to local, domestic and export buyers on one platform Two platforms: (1) IGrain Offerboard – grower can publish grain to market and maintain ultimate control over final marketing decision (2) IGrain Exchange – grower can place firm offer for warehoused grain at GrainCorp and AWB Grainflow sites	C (IGrain)	N	Connection required (online)
Farmlogs Advantage https://farmlogs.com/	• Field information, alerts and recommendations on a variety of farm operations • Data entry features available in Australia Limited data for some variables	I (Farmlogs, US)	B	Offline use (after download)
Farm Lens/Field Health Report http://agribotix.com/	• Drone technology and data service provider • Suitable for: Vetch, Wheat, Canola, Tomatoes, Barley Survey field and send information and data to Farmlens for processing/viewing results	I (Agribotix, US)	B	Connection required (update/sync data)
Agrivi Farm Management https://www.agrivi.com/	• Plan, monitor and analyse farm activities • Suitable for: fruit, vegetable and crops Plan, monitor and analyse farm activities, weather, finances, inventory, growing analytics/reports	I (Agrivi, UK)	B	Connection required (update/sync data)

Product	Description/Features	Business Model	Scope	Connectivity
FindmySeed https://www.morningfarmreport.com/findmyseed	• Corn and soybean seed selector • Identifies best seed options using information regarding soil type, farming practices and yield data • Suitable for: corn, soybeans, wheat, barley, peanuts, oats, cotton	I (Agrible, US)	N	Connection required (online)
Farm at Hand https://www.farmathand.com/home	• Manage entire farm operation • Track and monitor field activities • Supports offline mode (for iOS) Features: - Manage field records - Inventory management - Contracts	I (Farm at Hand, Canada)	B	Connection required (update/sync data)
Conservis http://conserviscorp.com/en/	• Farm management software • Tools for: - Planning - Budgeting - Inventory - Harvesting - Work Orders Suitable for: row and permanent crops	I (Conservis, US)	B	Connection required (update/sync data)
AgGuide software https://www.farmscanag.com/	• On screen visual guidance for controlled traffic row crop operations • Record, storage and analysis of fields, jobs, field perimeters, spray and weather data • Retain mapping for full record of in-field jobs, fertilizer, spray and harvesting operations Variable rate control (chemical/fertiliser rate control)	C (FarmscanAg)	B	Offline use (after download)

Product	Description/Features	Business Model	Scope	Connectivity
Yield Prophet http://www.yieldprophet.com.au/yp/WhatIsYP.aspx	• Online crop production package • Crop production model (APSIM model) Generates crop simulations and reports e.g. crop report – yield range, quantity of available nitrogen and water resources	P (Birchip Cropping Group and GRDC)	N	Connection required (online)
eFarmer https://efarmer.mobi/	• GPS navigation system and automated record keeping • Store field records – type of operation, fertilisers, pesticides • Fieldwork maps and records • Secure data on cloud • Software and hardware packages Farm GPS App – tractor GPS navigation, automatic record keeping, excel reports Farm tracking App – tracking software, includes mapping, crop history and calculations of materials used, excel reports	I (Netherlands)	B	Connection required (update/sync data)
Agridigital http://www.agridigital.io/	• Cloud based commodity management system • Blockchain technology where records cannot be changed, edited or deleted • Smooths transactions and speeds up payments • Provides grains provenance Current trial in grains with CBH group trail sale of organic oats at Blue Lake Milling, SA	Startup (Agridigital)	N	Connection required (update/sync data)

Product	Description/Features	Business Model	Scope	Connectivity
ProductionWise https://productionwise.com.au/	• NDVI Satellite imagery and field mapping • Paddock record keeping and planning • Grain storage record keeping and contract information Comprehensive reporting and operation templates for quick data entry	C (Graingrowers)	B	Offline use (update/ sync data)
iCropTrak https://icroptrak.com/	• Farm data management and compliance tool • Collect and record data from field, zone, row levels Track crop quality, water, chemicals	I (CropTrak, US)	B	Connection required (update/sync data)
Climate Fieldview https://www.climate.com/	• Field data and imagery tool • Crop performance reports Field health maps for comparison and field variability	I (Climate Corporation, US)	B	Offline use (after download)
SAP Farm Management (Vistex) https://www.vistex.com/	• Collects, aggregates and analyses field data • Chemical compliance Access through mobile app	I (Vistex, US)	B	Connection require (update/sync data)

Product	Description/Features	Business Model	Scope	Connectivity
FarmFlo http://farmflo.com/	• Farm management software • Map fields using the mapping tool • Record spray and fertiliser activities via an app Cloud based	I (Farmflo, Ireland)	B	Connection required (update/sync data)
APUNGA https://www.apunga.com/ HELPING FARMS TO GROW	• Horticultural farm management system • Manage crop lifecycle, planting, fertiliser, weeding • Harvest management • Inventory and order control Suitable for Horticulture industry	C (Apunga)	B	Connection required (update/sync data)
Satamap http://satamap.com.au/	• Satellite imagery • Crop growth and yield forecasting Identify areas of low and high growth for more targeted solutions, targeted fertiliser and insecticide applications	Startup (Satamap)	N	Connection required (update/sync data)
Cabbige http://www.cabbige.com/	• Business management tool designed for small scale farms • Detailed inventory tool – track and monitor inventory • Review farm records	I (US)	B	Connection required (update/sync data)

Product	Description/Features	Business Model	Scope	Connectivity
Yield Gap Australia http://www.yieldgapaustralia.com.au/wordpress/	• Interactive map based tool for grain growers (wheat and canola) and agronomists • Extent and geographical distribution of yield gap (actual and potential yield)	P (GRDC & CSIRO)	N	Connection required (online)
Grownotes Alert https://grdc.com.au/resources-and-publications/grownotes/alerts	• Notification and information service that delivers urgent and important alerts on specific incidence, prevalence and distribution of costly weeds/disease/pests and biosecurity emergencies Nominate specific farm locations/zones and crop type	P (GRDC & DEDJTR)	N	Offline use (after download)
Cropscan 3000H system https://www.nextinstruments.net/index.php/products/cropscan	• Accurate measurement of protein, moisture and oil in wheat and canola crops via remote sensor sampling head • Upload data to Team viewer program to run diagnostics and analyse data Generate field maps to optimise fertiliser program	C (NextInstruments)	N	Connection required (sync/update data)
Yield Gap Australia http://www.yieldgapaustralia.com.au/wordpress/	• Interactive map based tool for grain growers (wheat and canola) and agronomists • Extent and geographical distribution of yield gap (actual and potential yield)	P (GRDC & CSIRO)	N	Connection required (online)

Sector Specific:

Product	Description/Features	Business/ Business Model	Scope	Connectivity
Cotton				
CottASSIST https://www.cottassist.com.au/Default.aspx	• Range of web based tools to deliver latest cotton research and up to date information • Support adoption of best practice in cotton crop management • Assess crop progress and assists in decision making so crops are grown efficiently	G (CSIRO)	B	Connection required (online)
FastStart Tools https://www.syngenta.com.au/faststart-tools	• Program developed to screen technology • Supports the development of practical tools for cotton growers • Contributed to 25 industry research projects Tools include: - Cotton planting rate calculator - Replant calculator - Variety performance comparison	P (Syngenta and CSD)	B	Connection required (online)
Sugar				
Qcane Select	• Helps determine varieties that are best suited for farm conditions • Provides variety information, farm planning, regional reporting	RDC (SRA)	N	Connection required (online)

Product	Description/Features	Business/ Business Model	Scope	Connectivity
Irrigweb http://www.irrigweb.com/	• Sugarcane irrigation scheduling tool for the sugar industry • Provides irrigators with local and current advice on sugarcane water crop use and development • Uses crop water use estimates and irrigation constraints defined by the user, crop cycle inputs to schedule future irrigation • Uses the sugarcane crop model, CANEGRO to calculate sugarcane water use and yield output	C (Irrigweb)		Connection required (online)
Wine				
Vinsight (winery software) https://www.vinsight.net/home?utm_expid=127308502-4.2HLgX5U2QiaTP0AamcqoJg.1&utm_referrer=https%3A%2F%2Fwww.vinsight.net%2Fhome	• Software and app • Track and trace production • Monitor fermentation data • Manage inventory, production and sales	I (Vinsight, NZ)	B	Connection required (update/sync data)
Sky Squirrel https://www.skysquirrel.ca/	• Crop analytics and data storage • Drone based technology for monitoring crop health • Quick and reliable detection of grapevine disease • Image analysis and reports to manage plant health and disease	I (SkySquirrel Technologies, Canada)	N	Connection required update/ sync data)

Livestock Management:

Product	Description/Features	Business Model	Scope	Connectivity
AgBoost https://ag-boost.com/	• Analyze, manage and improve performance and genomics data • Cloud based platform • Personalised genetic database, genetic information to provide guidance to producers on how to feed livestock, breed and forecast value of herd • Genomic profiling – input genetic information about individual and/or herds of animals, to rank and/or sort animals based on specific genetic merit and/or traits of interest • Valuation and forecasting – conducted through collection of relevant genomic data incorporated with real-time market data about the agriculture products (e.g., feed prices, sale barn data) • Easy visualization of a genetic profile, performance qualities and marketability	I (Agri-Bioformatics, US)	N	Connection required (update/sync data)
MINDA - MindaLive - MindaApp - MindaMilk - MindaLand7Feed - MindaWeights - Minda Pro http://www.lic.co.nz/lic_MINDA.cfm	• Suite of products: MindaLive, MindaApp, MindaMilk, MindaLand7Feed, MindaWeights, Minda Pro • Record and store herd data, pasture levels • Live weight analysis tools for developing stock to full potential	I Co-op (LIC, NZ)	B	Connection required (update/sync data)

Product	Description/Features	Business Model	Scope	Connectivity
Cattleworks http://www.cattleworks.com/home.aspx?ObjectId=9	• Manage and maintain animal or herd records, data can be used to analyse herd and animal health, productivity and potential profit • Data is stored on internal database • Cattle entry – enter cattle into program, record sales and purchases, record births, losses and medical events • Reports – generate reports related to inventory, cow performance, medical records etc.	I (Cattleworks, US)	B	Offline use (after download)
Industry Inventories http://industryinventories.com.au/	• App and website • Two inventories and two product databases covering pesticides and animal health, record information and run reports • Create and maintain accurate records of chemicals used in operations	C (Industry Inventories)	B	Connection required (online)
Maia Grazing http://maiatechnology.com.au/	• Online grazing management tool • Record and store livestock numbers, movements, grazing records, purchase and sales • Production analysis and scenario based forecasting to understand future performance	C (Maia Technology)	B	Connection required (online)
CloudHerd https://cloudherd.com/	• Online stockbook, farm management and online livestock trading directly linked to stockbook • Aims to make it easier to buy and sell cattle online • Record and track animal performance/feed levels • Import animal data/information into online livestock trading platform	C (CloudHerd)	N	Connection required (update/sync data)

Product	Description/Features	Business Model	Scope	Connectivity
Pasture io/MilkFlo io https://pasture.io/ https://milkflow.io/	• Grazing planner to increase pasture utilisation, using herd nutritional requirement data • Accessible from smartphone, tablet or computer • Track paddock performance including growth rates, nutrition and other general properties	C (Pasture io)	B	Connection required (update/sync data)
Herdmaster - Commercial - Small - Stud http://herdmaster.abri.une.edu.au/	• Livestock recording and reporting, benefits: view entire animal history, customise treatments, automatic calculations • Integration with breed societies, NLIS and BREEDPLAN	C (Agricultural Business Research Institute (ABRI), UNE)	N	Connection required (import/export, sync data)
ILR2/ILR Online https://abri.une.edu.au/Docs/pdf_ilr2brochure.pdf	• Breed register software • Breedplan service used to undertake genetic evaluations for 45 beef breeds • Online real-time application for active animal herd management, inventory maintenance, performance data entry	C (ABRI, UNE)	N	Connection required (update data)
FarmStock/ Financial Manager http://www.farmplan.com.au/farm-stock/	• Recording keeping system for both animal information and financial history • Suitable for beef, sheep and goat producers • Record complete history of animal, maintain purchase and sale records, track animal characteristics and history, record stock movements by animal, mob or paddock, Budgeting and accounting tools	C (Farmplan)	B	Offline use (after download)

Product	Description/Features	Business Model	Scope	Connectivity
KoolCollect, KoolPerform, KoolStock http://www.sapien.com.au/	• Individual animal data collection tool • Record and calculate weights and weight gains • Access all animal history records offline, data analysis and reporting KoolStock – smartphone app • make comments and set alerts, information sent to cloud	C (Sapien Technologies)	B	Connection require (update/sync data)
Drought feed calculator https://itunes.apple.com/au/app/drought-feed-calculator/id921986324?mt=8	• Determine minimum feed requirement for range of animals • Suitable for sheep/cattle • Feeding rations for sheep and cattle by calculating daily feed requirements of animals, in both drought and normal year • Calculate the total amount of feed required per head and for a mob of animals, over period of time	G (NSWDPI)	N	Offline use (after download)
Stocktake Plus http://www.stocktakeplus.com.au/	• Monitor land conditions and stock numbers • Produce reports • Calculate right balance of stock to pasture, store rainfall records • Identify land type via mapping tool • App available	P (DAF QLD through FutureBeef program & Livestock Australia)	B	Offline use (after download)

Product	Description/Features	Business Model	Scope	Connectivity
Automed https://automed.io/	• Weight based dosing system • Automatically calculate, deliver and record livestock treatments/medication • Records are captures and synced with cloud • From app can completely control and manage the Automed delivery device • Connects to RFID readers via bluetooth, app and web portal	Start-up (Automed)	N	Connection required (update/sync data)
MLA Market Info app https://itunes.apple.com/au/app/mla-market-information/id874155835?mt=8	• Provides red meat industry with timely and relevant market information on industry trends • Suitable for beef, sheep, goat • Access to 70 sale yard market information and data • Keep up to date with prices and supply of cattle, sales volume and slaughter numbers	RDC (MLA)	B	Connection required (online)
Aglive Pro (App/Web) - Pro producer - Pro enterprise - Pro corporate https://aglive.com/aglive-farm-manager-pro/	• Livestock management software via mobile app or web • Map paddocks, monitor feed and treatment, visibility of animal movements from pick up to receival • Convenience of online compliance and traceability in line with industry requirements (link w/ NLIS) • Make animal information changes through eNVD (electronic national vendor declaration) • RFID scanning equipment for ease of animal scanning and traceability • Use with beef, sheep and goat	P (Aglive and MLA)	B	Connection required (update/sync data)

Product	Description/Features	Business Model	Scope	Connectivity
Sense T Pasture predictor http://www.sense-t.org.au/projects-and-research/agriculture	• Online pasture productivity tool to predict and prepare for livestock feed availability • Generates a 30-day forecast of how much pasture will grow in their area • Uses a range of data from rainfall events and climate records, real-time soil moisture • Aimed at beef and dairy farmers but is suitable for cropping • Currently for Tasmania but looking to rollout the tool across Australian states as model is refined	P (Tasmanian Institute of Agriculture, CSIRO, Sense T)	N	Connection required (online)
OPPIS (Online property and planning information software) http://www.nrmhub.com.au/mapping-2/	• Data and mapping tools to develop digital property plans • Allows for mapping, reporting and analysis • Analyse land conditions, property utilisation and plan for grazing development	P (NRM Hub – 14 Industry Partners)	N	Connection required (online)
FarmGraze http://www.mobilefarmapps.com/apps.html	• Measure, record and manage grazing system • Suitable for dairy cows, beef and sheep • Record grass measurement data • Store records of livestock movements	I (Mobile Farm, U.K University)	N	Offline use (after download)

Product	Description/Features	Business Model	Scope	Connectivity
Stockplan http://archive.dpi.nsw.gov.au/content/science-and-research/economic-reports/economic-research-reports/err35	• Collection of decision support tools enabling cattle and sheep producers to explore management options in the event of drought • DroughtPack – drought risk management tool, estimate feed requirements and feed costs	P (NSWDPI and AWI)	B	Offline use (after download)
BreedCow and Dynama Software https://www.daf.qld.gov.au/animal-industries/beef/breedcow-and-dynama-software	• Software packages designed to plan, evaluate and improve profitability and financial management of extensive beef cattle enterprise Breedcowplus – compare profitability of herd under different management systems DynamaPlus – make forward projections of herd numbers, sales, cashflow, net income, debt	G (DAF QLD)	N	Offline use (after download)
GrassGro http://www.grazplan.csiro.au/	• Computer program • Assess risk that variable weather conditions impose on a grazing system • Quantifies variability in pasture/animal production • Test management options against a range of seasons for sustainable use of land, user inputs livestock, management, cost, prices	G (CSIRO)	N	Connection required (online)
GrazFeed http://www.grazplan.csiro.au/	• Computer program • Calculate the daily nutritional requirement of sheep and cattle • Can be applied to any breed/class of sheep or cattle	G (CSIRO)	N	Connection required (online)

Product	Description/Features	Business Model	Scope	Connectivity
MetaFarms - Assurance - Finish - Sales - Feed - Analytics - Flock http://www.metafarms.com/products.html	• Suite of modules to help manage and gain insight into livestock production systems • Software platform and data analysis for all phases of livestock production • Range of livestock management apps to manage farm information • Set up feed budgets, monitor usage, verify feed mill performance • Track diet and ingredient pricing, gain understanding of feed costs	I (MetaFarm, US)	B	Connection required (sync/update data)
Moocall https://au.moocall.com/ Moocall connecting you to your animals	• Calving alert system • Sensor technology is used to send alerts on animal contractions and predict when a cow will give birth • Receive notifications via SMS, app, email	I (Moocall, Ireland)	N	Connection required (update data/receive alerts)

Industry Specific:

Product	Description/Features	Business Model	Scope	Connectivity
Alpaca				
Optimate AlpaFarm https://www.alpafarm.com/	• Herd and farm management software • Specific to alpaca breeders • Import data and create reports • Five modules: - Breeding Cycle module - Alpacas Module - Paddocks Module - Finances Module - References Module	C (Optimate Computer Systems)	B	Offline use (after download)
Goats				
EasyKeeper https://www.easykeeper.com/	• Livestock records management system • Store animal profiles and enter herd records Features: - Task management - Weight Tracking - Body condition scoring - Health management reminders - Store identity information	I (US)	B	Connection required (online)

Product	Description/Features	Business Model	Scope	Connectivity
Beef				
Farmecco https://www.agrihive.com/#/home	• Financial literacy tool specifically for beef producers • Input information and develop comprehensive financial and production reports of business • Access to relevant and up to date information and data – draws on major databases including MLA NLRS market reports and ABARES • Instant CBA of selling cattle now vs. holding them to add more weight	P (Agrihive & MLA)	B	Connection required (online)
Beefspecs Calculator http://beefspecs.agriculture.nsw.gov.au/	• Manage cattle to meet weight and fat specifications • Assess and monitor animal growth/performance • Allows for changes in management practices if compliance isn't met to achieve optimal animal sale condition	P (NSWDPI & MLA)	N	Connection required (online)
Dairy				
EasyDairy/ Easy ID http://www.easydairy.com.au/easy-dairy/	• Platform that allows farmer to import, view and update herd information and deliver to relevant breeding/herd recording centres • View milk volumes and average milk production, monitor individual feeding and production	C (Easy Dairy Automation Systems)	B	Offline use (after download)

Product	Description/Features	Business Model	Scope	Connectivity
Rumen8 http://www.rumen8.com.au/	• Design diet to ensure cow's dietary requirements are met through a tested nutrition mode • Store and compare different diets • Can enter feed and milk prices to view changes in production and return	RDC (Dairy Australia and Western Dairy)	N	Offline use (after download)
Countdown Mastitis Toolkit (Dairy Australia) https://itunes.apple.com/au/app/countdown-mastitis-toolkit/id710948379?mt=8	• Access to mastitis control information • Range of tools and calculators for better control and management of mastitis in Dairy herds • Supports improvements in cow health and milk quality • App available	RDC (Dairy Australia)	N	Offiline use (after download)
Silent Herdsman http://www.afimilk.com/	• Neck collar monitoring system • Detects health problems in cows based on cow activity, rumination and eating patterns • Data transmitted wirelessly from collar via base station to computer that will issue alerts indicating illness • Automatic identification of cows that require treatment	I (Afimilk, Israel)	N	Connection required (update/sync data)

Product	Description/Features	Business Model	Scope	Connectivity
Pro Grass Rotation/ Pro Milk Solids/Pro Dairy Event http://www.smartfarmapps.com/farming-apps/	• Manage grazing decisions across paddocks • Calculate milk solids per Ha and record to analyse milk solid data • Track and receive alerts for key cow events e.g. medication • Helps farmer understand supply/demand of grass and maximise pasture utilisation	I (Smartfarm Apps, Ireland)	N	Offline use (after download)
BOVControl https://www.bovcontrol.com/en	• Data storage platform to improve animal health and increased milk production • Input and store basic animal data (birth, medication, vaccines, weight) • Use any technology to log cow data e.g. ear tag, bluetooth collar that can collect temperature and location data • Traceability advantage • Register disease and vaccines and receive notifications on events • App uses this data to make predictions	I (US start-up)	B	Connection required (update/sync data)

Soil management:

Product	Description/Features	Business Model	Scope	Connectivity
SoilMate http://www.backpaddock.com.au/	• Software package for interpretation and analysis of soil and plant nutrition data • Mapping/logging samples	C (Back Paddock Company)	N	Connection required (online)
Nulogic Sampling Pro (App) https://www.csbp-fertilisers.com.au/nutrition-services/nulogic-soil-and-plant-analysis	• Soil and plant sample analysis • Assists with fertiliser decisions through soil and plant sample analysis • Send samples to lab and receive • Record location and match sample to location and receive a report of the results	C (CSBP)	N	Connection required (update/sync data)
SoilMapp https://www.csiro.au/en/Research/AF/Areas/Sustainable-farming/Decision-support-tools/SoilMapp	• Provides soil information (physical and chemical characteristics) from Australia's national soil databases (Australian soil resource information system, ApSoil) • Assists in land management decisions	P (CSIRO, GRDC, Australian Collaborative Land Evaluation Program)	N	Connection required (online)
ApSoil	• Database of soil water characteristics • Enabling estimation of plant available water capacity for soils and crops • Develop unique directories of locally relevant soils	P (CSIRO, Uni of QLD, Department of Ag. And Fisheries, Agresearch Limited, Uni of Southern QLD)	N	Connection required (for download)

Water/Irrigation management:

Product	Description/Features	Business Model	Scope	Connectivity
Crop irrigation requirement calculator https://www.agric.wa.gov.au/irrigation-calculator	• Broad guidance of water requirements for commercial crops in WA • Suitable for crops in Western Australia	G (DAFWA)	N	Connection required (online)
SoilWater App http://www.soilwaterapp.net.au/	• Estimates soil water using BOM and local rainfall records • Provides estimates of plant available water, low cost grower friendly app, detailed analysis page is provided	P (GRDC, USQ)	N	Connection required (for download)
Idroplan http://idroplan.org/	• Smart irrigation system measuring important soil parameters Features: - Whether forecast integration - Web App that provides water information	Start-up (Idroplan)	N	Connection required (update/sync data)
Farm Connect Software http://www.rubiconwater.com/catalogue/farmconnect/	• High flow precision surface irrigation, monitor crops and manage irrigation using wireless soil moisture probes • Weather stations, rain gauges – manage irrigation online, choose water sequencing and receive alerts if there are any problems associated with the irrigation process	I (Rubicon Water)	N	Connection required (update/sync data)

Pest/Disease management:

Product	Description/Features	Business Model	Scope	Connectivity
Weedsmart App https://weedsmart.org.au/	• Determines the risk that a particular paddock may have to herbicide resistance • Assess herbicide resistance and weed seed bank risk	RDC (GRDC)	N	Offline use (after download)
Weed Seed Wizard https://www.agric.wa.gov.au/weed-seed-wizard-0	• Computer simulation tool that applies to all grain growing areas of Australia • Predicts weed emergence and crop losses • Helps growers understand and manage weed seed banks • Looks at how different weed management techniques, irrigation, harvesting management practices affect weed numbers	P (GRDC, DAFWA, UWA, University of Adelaide, NSW DPI, QLD Department of Agriculture, Fisheries and Forestry)	N	Connection required (for download and updates)
Weed ute guide https://grdc.com.au/resources-and-publications/app	• Identification of the most common types of weeds in paddocks across Australia • Allows growers to search, identify and compare photos from the app to the ones taken from their own paddock	RDC (GRDC)	N	Offline use (after download)
Plantix http://peat.technology/	• Plant disease diagnostic app, receive results automatically after submitting picture • Beta Version so not adapted to country and regional diseases	I (PEAT, German based agtech start-up)	N	Offline use (after download)

Product	Description/Features	Business Model	Scope	Connectivity
Pest Track http://www.pesttrack.com.au/	• Farmer can track and record the trapping of pests (QLD fruit fly) enabling species identification and early detection of outbreak	C (Advance Computing)	N	Connection required (online: download/update data)
FeralScan https://www.feralscan.org.au/	• Record and map feral animal sightings and damage - RabbitScan - WildDogScan - FoxScan - FeralPigScan - ToadScan - FeralGoatScan - FeralFishScan	P (Industry, Gov and Business collaboration)	B	Connection required (online)
PestGenie Ultimate http://www.pestgenie.com.au/DefaultPG.aspx?ReturnUrl=/	• Automates management of farm chemical safety information • Provides comprehensive information on crop protection and animal health products Modules include: - (M)SDS Management - Spray Diary - Chemical Inventory Management - Crop Protection Expert - Chemical/Non-Chemical Risk Management	C (PestGenie, Canberra)	N	Connection required (update/sync data)

Product	Description/Features	Business Model	Scope	Connectivity
Paraboss – Wormboss – Flyboss (Sheep CRC) – Liceboss (AWI) https://www.paraboss.com.au/	• Products developed for management of blowflies, lice and worms • Provides information on the management of major parasite risks for sheep and worms in goats	P (Sheep CRC, AWI)	B	Connection required (online)

Climate:

Product	Description/Features	Business Model	Scope	Connectivity
RAINMAN Streamflow https://www.daf.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/cropping-efficiency/rainman	• Software package that uses historical weather records to forecast seasonal rain flow and streamflow • Improve climate risk management • Analyse rainfall and other climate variables	G (DAF QLD)	N	Offline use (requires connection to receive monthly updates)
Sensing+ for Agriculture/Aquaculture http://www.theyield.com/	• Sensing+ for Aquaculture – collects real-time data from sensors that sit in the water and outside water to analyse quality of water and climatic conditions • Data is put through predictive models to produce a three day harvest area forecast for more informed decision making • Record important harvest details such as grading/mortality rates • Track multiple water and weather points	Start-up (The Yield)	N	Connection required (update/sync data)
Fires near me http://www.rfs.nsw.gov.au/fire-information/fires-near-me	• Information on current bushfires and other incidents • Provides up to date warnings on fires across NSW	G (NSW Rural Fire Service)	N	Connection required (online)

General Business/Finance/Operational:

Product	Description/Features	Business Model	Scope	Connectivity
Agrimaster https://www.agrimaster.com.au/	• Accounting and Financial software program • Used for reporting, budgeting, wages, handle day-to-day accounts and cashbook • Stock/inventory control	C (Mastergroup)	B	Offline use (after download)
Phoenix Farm Management Software (AGDATA) https://www.agdata.com.au/	• Production and financial software modules • Provides both a live and desktop solution Financial software – financial and budget packages, available in three levels to manage production and cash flow: - Financial lite - Financial - Financial pro - Production products: - Mapping: property planning tool, create comprehensive property maps using individual farm data to visually manage business - Cropping: collect extensive range of data, complete crop production recording, season and performance reporting, create cropping plans - Livestock: collect livestock data, generate performance analysis, track animals, connects with NLIS database - Grazing: collect data and analyse grazing performance, quantify pasture productivity, identify grazing rotations, use information to monitor grazing system - Weather: capture weather data, integrated with grazing module to track grazing performance back to weather events	C (Agdata)	B	Connection required (sync/update data)

Product	Description/Features	Business Model	Scope	Connectivity
AgTribe https://www.agtribe.com.au/	• Advertise equipment/machinery for hire, • Those looking to hire equipment can search and find a piece of machinery in cost effective and efficient way	C (Agtribe)	N	Connection required (online)
Agritrack http://agritrack.com.au/products/	• Farm logistics management tool • Connect to tablet and beacon devices, • Software to be used anytime regardless of quality of connection, dashboard with cloud access	C (Agritrack)	N	Connection required (update/sync data)
Operations Centre/ Mobile Farm Manager https://www.deere.com.au/en_AU/products/equipment/agricultural_management_solutions/information_management/myjohndeere/myjohndeere.page	• Single website/dashboard • Manage production, equipment, operations data, • JD Link Connect – view information about machines and wirelessly send data from machines to operations centre	I (John Deere, US)	B	Connection required (update/sync data)
PS Stockbook/Farmbook https://www.practicalsystems.com.au/	• Livestock software, analyse weight gain/fertility • Package for cropping, pasture, livestock, weather, machinery, record paddock, livestock details • Access to over 70 analysis reports • Help identify costs of operation, monitor livestock, manage compliance and quality assurance	C (Practical systems)	B	Offline use (after download)

Product	Description/Features	Business Model	Scope	Connectivity
i-Agri https://www.iagri.com/	• Online dashboard Features: - Mapping - Staff management - Identify and report farm hazards and incidents - Fleet/equipment records - Task scheduling	I (i-Agri, NZ)	B	Connection required (online)
3D Farm Modelling http://www.droneag.com.au/	• Farm planning, mapping and monitoring • GPS tractor and harvester maps • Variable rate irrigation maps • Model different weather patterns and irrigation rates	C (DroneAg)	B	Connection required (import data)
Complete Farm Operations/ Farm Chemical Management http://www.farmminder.com.au/solutions	• Access to data analysis tools and detailed reports on farm operations facilitating compliance with industry requirements • Operations planning, reporting and analysis of farm • Spray diary, pest infestation and treatment area mapping Crop protection expert – find most suitable pesticide or animal health product to address a specific pest SDS Management – real time access to up to date farm chemical information	C (Farm Minder)	B	Connection required (update/sync data)

Product	Description/Features	Business Model	Scope	Connectivity
PAM (Process, Analyse, Manage) http://www.fairport.com.au/en/pam-process-analyse-manage/pam-process-analyse-manage	• Solutions for horticulture, cropping and livestock, viticulture • Plan and record farm activities • Track costs and income • Import data from soils • Analyse water use efficiency	C (FAIRPORT Farm Software)	B	Connection required (update/sync data)
Farmer Mobile and Farmer Plus https://www.agworld.com.au/farmers	• Data collection, interactive maps, product and pest information to comply with requirements • Crop and pest pressure monitoring tasks – data in real time for use in reports or save in excel for analysis and reference at later date	C (Agworld)	B	Offline use (update/sync data)
Back Paddock Manager, Mobile, Adviser http://www.backpaddock.com.au/	• Planning, recording, reporting and mapping • Prepare what if scenarios based off management practices	C (Back Paddock Manager)	B	Offline use (after download)
Farm Manager/Contractor App http://stringybarksoftware.com/	• Record cropping, livestock and machinery procedures • Crop chemical and fertiliser use records • Stock details e.g. breed, ear tag numbers and machinery maintenance FarmContractor – help contractors record clients job details and procedures	C (Stringybark Software)	B	Offline use (after download)

Product	Description/Features	Business Model	Scope	Connectivity
Observant Global http://observant.net/	• Suite of data analytics and support tools – cloud based decision support platform, supports wide range of information sources from crop and pasture to livestock and irrigation • Connects to range of hardware, both equipment and sensors Applications – crop manager application, irrigation scheduling application, analytics dashboard	C (Observant)	B	Connection required (update/sync data)
Farmware App http://www.farmware.net/about/	• Record activities for livestock, paddock and storage • Keep track of livestock numbers, maintain animal treatment record • Record paddock usage, analyse paddock and crop performance, maintain basic storage inventories • Use via smartphone, tablet or PC	C (Farmware)	B	Connection required (sync data to cloud/update data)
SenseAg https://www.senseag.com/	• Sensor network data – view live sensor data e.g. relative humidity, winds speed, rainfall, soil moisture • View satellite, aerial, drone imagery with geodata tools • Track stock • Generate detailed reports and receive alerts and notifications	Start-up (SenseAg)	B	Connection required (live data feed)

Product	Description/Features	Business Model	Scope	Connectivity
Figured https://www.figured.com/	• Production and financial information, budgeting and forecasting Production tracking: Crop farmers – track tonnage by grade, production, operating expenses Livestock farmers – births, deaths, sales and purchases Dairy farmers – track milk production and update forecast when prices change	Start-up (Figured, NZ)	B	Connection required (update/sync data)
Smart Elements https://smartelements.io/	• Sensor devices connected to base station – developer kit, water kit, weather kit • Variety of sensors that report data back to an online dashboard, SMS and email alerts when system requires attention	Start-up (Smart Elements)	B	Connection required (update/sync data)
Adventive http://www.adventive.me/	• Investment platform – connects agribusiness and producers with funds • Producers use it to access funding that they can't otherwise access from their bank to leverage performance	Start-up (Adventive)	N	Connection required (online)
F-Track Live http://www.farmapps.com.au/f-track-live-new	• Farm management app and dashboard • Export data collected from other platforms • Rainfall records, chemical inventory, labour records • Variety of modules: livestock manager, crop manager, task management, paddock, silo manager, fuel inventory	Start-up (Farm Apps)	B	Connection required (update/sync data)

Product	Description/Features	Business Model	Scope	Connectivity
AgriWebb Notebook http://www.agriwebb.com/ AgriWebb	• Farm and livestock management app • Create detailed reports to meet business requirements Features: - Map builder for visual management, livestock record keeping and analysis - Stock numbers and movements, feed, animal treatment - Records for pasture and crop e.g. fertiliser/seed/pasture type/input costs, inventory - Monitor outstanding and completed tasks - Generate comprehensive financial and farm performance reports for analysis	Start-up (AgriWebb)	B	Connection required (update/sync data)
Tractor Tracker App (On the Go Farm) http://www.tractortrackerapp.com/home.html	• Store information on farm machines for quick identification e.g. name, make, model, keep track of service and maintenance work • Set reminders for maintenance and service so machines are ready to use in the field • Cloud based	I (US)	N	Offline use (after download)
Agri360 https://www.agrimap.com/ AGRIMAP	• Farm record keeping and task management on phone, tablet, desktop • Quick and easy access to all farm information, farm timeline and map • Set plans for coming year • Cloud based with use of real time data	I (Agrimap, NZ)	B	Connection required to sync/update data)

Product	Description/Features	Business Model	Scope	Connectivity
Farmbrite http://www.farmbrite.com/features	• Online dashboard • Record information, financial details, activities of crops, livestock and staff • Farm planning and management through shared multi-user account • Schedule crop plantings, harvest and maintenance	I (farmbrite, US)	B	Connection required (online)
Cultura Farm software solutions http://www.culturatech.com/	• Various management systems • Agroguide agronomy management – improved crop planning, spatial management, field history and reporting AGRIS business management tool – bank management, accounts payable/receivable, inventory management OneFreight – transportation management system	I (Cultura Technologies, US)	B	Connection required (update/sync data)
Farmer Productivity Insight http://www.awhere.com/products/farmer-productivity	• Range of apps – farm insight, daily crop, weekly crop • Historic and forecasted weather information • Alerts on pests and disease • Crop specific information and planting recommendations	I (aWhere, US)	B	Connection required (receive alerts)
AGBIZ Farm Budgeting Tools https://www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/agribusiness/agbiz	• 250 AGBIZ tools • Excel spreadsheets with already available data, farmer provides additional farm data • Designed for QLD farmers but can applied to farms across Australia • Calculators for plants, fisheries, animals, farm business and finance	G (Business Queensland QLD Gov.)	B	Offline use (after download)

Product	Description/Features	Business Model	Scope	Connectivity
WALI https://www.daf.qld.gov.au/environment/ag-land-audit/web-mapping-tool Queensland Government	• Mapping tool, access to audit information from the QLD Land Audit • Broad range of applications, identifies locations of processing facilities and potential areas for cropping, horticulture, sugar cane etc.	G (Department of Agriculture and Fisheries, QLD Gov.)	N	Connection required (online)
Agdraft https://www.agdraft.com.au/ AgDraft | get your labour sorted	• Online agri labour platform • Connects workers to farm operators • Matches workers and farmers based on their requirements e.g. skills/location • Workers have been verified by previous employers	Start-up (Agdraft)	N	Connection required (online)
Wi-Sky http://www.wi-sky.com.au/ WI-SKY	• Provides broadband internet for farmers and rural areas • Building network and delivering fast internet to people in country areas • Operating 20 internet access towers across NSW • Land based, high speed, private wireless network	C (Wi-Sky)	N	–
P2P Agri https://p2pagri.com.au/ P2PAgri	• Business analysis and reporting – develop key business reports e.g. balance sheet, profit and Loss, cash flow, KPI's • Access full farm business recording system from current activity, historical data and future planning • Scenario analysis – develop what if type scenarios using a 5-year horizon to make important business and planning decisions • Online platform supported by offline capacity	C (P2P Agri)		Connection required (update/sync data)

Product	Description/Features	Business Model	Scope	Connectivity
Farm Command https://www.farmersedge.ca/smartfarmers/	• Farm management platform Features: - Map manager: provides complete overview of fields, helps identify problem areas and opportunities, map comparisons - Weather Manager: provides forecasts, collect information on current conditions via weather stations, access to historical weather data, receive alerts - Equipment Manager: real time and historical tracking of equipment data - Job Manager: create to-do list, schedule events, set notifications - Asset Manager: oversee farm assets via list of fields including crop type and variety grown	I (Farmers Edge, US)	B	Connection required (update/sync data)
Trimble https://agriculture.trimble.com/software/	• Agronomic Services • Guidance and Steering • Yield Monitoring • Water management • Specialty Crops • Livestock Solutions Features: - Crop planning - Field record keeping including field task reports - Precision agriculture mapping and tools - Financial tools and farm accounting software - Desktop software for importing and managing precision farming data/field records/cash accounting - Mobile app for field records, fleet tracking	I (Trimble, US)	B	Connection required (update/sync data)

Product	Description/Features	Business Model	Scope	Connectivity
Drone Deploy http://flyingag.com.au/	• Drone and UAV mapping software to capture imagery, process maps and interpret data • Identify and asses crop variability and damage • Scout crops to detect disease • Keep track of livestock • Access to 30+ apps in the DroneDeploy interface	C (FlyingAg)	B	Connection required (update/sync data)

Emerging products – Australia:

Product	Description/Features	Business Name	Users
Ceres Tag http://www.cerestag.com/	• Smart ear tag for livestock • Complete identification and management ear tag for red meat, dairy, wool, pork, livestock industry • Information from the tag can be managed on mobile/tablet via software platform • Uses GPS tracking and unique property identification code (PIC) • Record change of animal ownership • Currently in development stage • Available to market at end of 2019 – start of 2020	Ceres Tag	Livestock producers – red meat, dairy, wool, pork
RapidAim http://rapidaim.io/	• Real-time alerts of the presence and location of fruit fly • Improve logistics of pest management through efficient response to fruit fly • Grid of low powered smart traps that detects the presence of fruit fly, sends an image to cloud for assessing and then alerts user • Trapping data allows for predictive modelling and pest forecasting • Recently completed first semi commercial trial • Collaborating with industry to refine first product offering • Projected to have traps and data packages available to customers within 12 months	RapidAim	Growers and producers affected by the presence of fruit fly

Product	Description/Features	Business Name	Users
EShephard https://agersens.com/eshepherd/	• Neck collar and app enabling farmers to fence, move, monitor livestock using a smartphone • Allocate fresh pastures and avoid areas inappropriate for grazing so improved health for animals • Reduce farm labour from moving cattle, reduce fence installation and maintenance Monitor stock remotely, check health state of animal, early disease detection	Agersons	Livestock producers
Sense T Viti-App http://www.sense-t.org.au/projects-and-research/agriculture	• Monitor on farm growing conditions • Assists in identifying disease and other production risks • Access to real-time information on growth conditions • Notification of high risk situations such e.g. frost and high winds • Not yet available commercially but in development stages	Partnership (Tasmanian Institute of Agriculture, CSIRO, Wine Tasmania)	Wine producers

Product	Description/Features	Business Name	Users
Spec-SINFER	• Soil analysis system • Current project involves testing of two devices: (1) Diffuse reflectance visible near infrared spectroscopy (visNIR) (2) Energy dispersive X-ray fluorescence spectroscopy (XRF) • The devices are used to collect data on soil texture, mineral composition, calcium carbonate content, cation exchange capacity, pH and organic carbon content • Data is used to provide more agronomically relevant properties e.g. water holding capacity, bulk density, hydraulic conductivity, pH buffering capacity • Soil properties are then mapped on a fine scale and are compared with crop growth and yield • Plans to release software with interest in commercialization following further testing • Plans to release a Beta version and standalone version	University of Sydney PhD project funded by GRDC	System is useful to anyone who uses soil information – growers, agronomists, scientists
FluroSat https://www.flurosat.com/	• Development of a predictive crop health monitoring and imaging system • Remote sensing imagery using hyperspectral cameras placed on drones or satellites • Conduct hyperspectral analysis to estimate crop performance • Increase accuracy in fertilizer application across paddocks • Identification of crop stress and deficiencies e.g. water and heat stress, weeds and disease • Currently undertaking commercial trials	FluroSat	Cropping industries - Involved in the Cotton X Program, supported by the Cotton Research and Development Corporation (CRDC) to adapt technology to cotton

Review of International Development and their Implications and Spillover to Australian Agriculture

Appendix 4.2 High – Medium – Low Levels of Technology Spill Over

Ag Data Needs Affected by farm variety, size, crop type, practice

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Appendix 4.2.1 CATTLE AND SHEEP

CASE STUDIES		COMPANY
CATTLE AND SHEEP	PASTURE MANAGEMENT	1. PASTURE MAP
CATTLE AND SHEEP	FLOCK MANAGEMENT	2. NORTRACE
CATTLE AND SHEEP	WATER MANAGEMENT	3. WATERFORCE + MICROSOFT + SCHNEIDER ELECTRIC

CATTLE AND SHEEP CASE STUDY 1: Pasture Management

1. PASTURE MAP
www.pasturemap.com
Founded: July 2014
Product: Application software
Investments: $1M
Headquarters: San Mateo, CA
Geographical Coverage: USA
Industries Served: Ranching
Company Overview: Grazing management and ranching software designed to improve cattle grazing and achieve grass fed certifications. The company uses intelligent mobile records, combined with aerial imaging, soil maps and rainfall data to help ranchers improve grazing practices, optimise land use and reduce livestock resource requirements for ranchers to map and subdivide pastures, record herd, animal weights, and plan water and infrastructure points.
Value Proposition: Subdivision planning tool from breakeven to profit in their first year.

CATTLE AND SHEEP CASE STUDY 2: Flock Management

2. NORTRACE

www.nortrace.com
Founded: 2014
Type: Private company
Product: IoT, application software
Headquarters: Sandnes, Norway
Geographical Coverage: Norway
Industries Served: IoT
Company Overview: Grazing management and ranching software designed to improve cattle grazing and achieve grass fed certifications. The company uses intelligent mobile records, combined with aerial imaging, soil maps and rainfall data to help ranchers improve grazing practices, optimise land use and significantly reduce livestock resource requirements enabling ranchers to map and subdivide pastures, record herd, animal weights, and plan water and infrastructure points.
Value Proposition: Subdivision planning tool has transformed current ranches from break even to profit in their first year.

CATTLE AND SHEEP CASE STUDY 3: Water Management

3. WATERFORCE + MICROSOFT + SCHNEIDER ELECTRIC
www.waterforce.co.nz
Founded: 2001
Type: Water management
Product: Water management solutions
Headquarters: Tauranga, NZ
Geographical coverage: 14 branches in NZ
Industries served: Sheep & beef, dairy, arable & cropping, viticulture, pip & stone fruit, vegetables, residential and commercial
Company Overview: To meet the growing need for effective irrigation, WaterForce developed SCADAfarm – an integrated automation and information management platform built on EcoStruxure Industry and Microsoft Azure technologies.

Appendix 4.2.2 GRAINS

CASE STUDIES		COMPANY	
GRAINS	SEED SELECTION TOOL	4. AGRIBLE	AGRIBLE
GRAINS	MACHINE-AGRONOMY DATA	5. CLIMATE FIELDVIEW	CLIMATE FIELD VIEW

GRAINS	FARMER DATA COOPERATIVE	6. FARMERS BUSINESS NETWORK	
GRAINS	FIELD RECORD KEEPING	6. VITAL FIELDS	
GRAINS	MONETISE MACHINE DATA	7. FARMOBILE	
GRAINS	MONETISE WITH WHOLESALERS	8. ADM ADVANTAGE PORTFOLIO	

GRAINS: Soils, weather, marketing, input use, efficiencies, robotics

GRAINS CASE STUDY 1: Seed Selection Tool

4. AGRIBLE

www.agrible.com
Founded: 2007
Type: Private company
Product: Agronomic analytics
Investments: $5M [ADM]
Headquarters: Champaign, IL
Geographical coverage: USA
Industries served: Growers and insurance

Company Overview: Offer seed benchmarking data, weather and field-specific analysis tools to help with on farm decisions. Customers include independent growers, software developers, soil test laboratories, crop consultants, insurance agencies, commodities companies, traders, and major ag chemical companies developing seed technologies and new production methods.

GRAINS CASE STUDY 2: Machine + Agronomy Data

5. CLIMATE FIELDVIEW

www.climate.com
Founded: 2012
Type: Public
Product: Agronomic analytics
Acquisitions: Precision Planting FieldView $220M; Climate $927M [Monsanto]
Employees: Over 500
Headquarters: Tremont, IL, San Francisco, CA
Geographical coverage: US, Canada
Industries served: Growers and retailers

Company Overview: The Climate Corporation, a subsidiary of Monsanto Company, aims to help all the world's farmers sustainably increase their productivity through the use of digital tools.
Product Overview: The integrated **Climate FieldView™** digital agriculture platform brings together field data collection, agronomic modeling and local weather monitoring to deliver simple mobile and web software solutions. The platform enables farmers to make informed operating decisions to optimize yields, maximize efficiency and reduce input costs.

GRAINS CASE STUDY 3: Farmer Data Cooperative

6. FARMERS BUSINESS NETWORK
www.farmersbusinessnetwork.com
Founded: 2014
Type: Private company
Investment: ~$83.9M in 5 rounds from 5 investors
Most recent funding: $40M Series C (March 2017)
Employees: 140+ employees
Headquarters: Sioux Falls, South Dakota
Geographical coverage: US moving into Canada
Industries served: Agriculture – commodity, specialty crops
Company Overview: Farmers Business Network (FBN) develops a farmer-to-farmer agronomic information network that uses data science and machine learning to share knowledge and gain trusted insights about their farms, inputs, and practices.
Products: The FBN agronomics platform allows farmers to upload a wide variety of data sets from their farms. FBN provides agronomic services like yield monitoring, weather data, and variable rate prescriptions. The data is then benchmarked anonymously against other farms in the US, the state, or even the county. The company has since expanded its product offerings to include agricultural input procurement services, crop marketing services, and financing.

GRAINS CASE STUDY 4: Field Record Keeping

7. VITAL FIELDS
www.vitalfields.com
Founded: 2011
Type: Acquired by The Climate Corporation on November 2016
Investment: $2.2 Million
Headquarters: Tallinn, Estonia
Geographical coverage: Estonian, German, Polish and Ukrainian markets
Product: Farm Management Software
Industries served: Farm management information systems
Company Overview: VitalFields offers a tool for farmers – Fieldbook – to plan, manage and analyse their field activities, including simplified tracking and reporting of all crop inputs to help

ensure compliance with the European Union environmental standards.

GRAINS [SWEET CORN, OIL SEED]: Data Monetization

GRAINS CASE STUDY 5: Monitise Machine Data

8. FARMOBILE
www.farmobile.com
Founded: 2013
Type: Private company
Investment: $5.5M Series A – Anterra Capital (Dec 2015)
Headquarters: Leawood, Kansas, USA
Geographical Coverage: US and Canada
Product: Machine Data
Industries Served: Agriculture – row crop
Company Overview: Develops and manufactures a PUC - passive uplink connection - devices that collect, analyse and manage data from machines for farmers. Farmobile is creating a marketplace where farmers can choose to sell their digital assets to vetted third-parties for the first time.

GRAINS Case Study 6: Monitise with Wholesalers

9. ADM Advantage Portfolio
www.admadvantage.com/adm-advantage-portfolio
Founded: 1902
Type: Public company (ADM - NYSE)
Revenue: $62.35 B USD (2016)
Employees: > 32,000 employees
Headquarters: Chicago, Illinois, USA
Geographical coverage: >160 countries
Product: Grain contracts, insurance
Industries served: Agriculture - grain marketing
Company Overview: ADM (Archer Daniels Midland Co.) processes cereal grains and oilseeds into products used in food, beverage, nutraceutical, industrial, and animal feed markets.
Product: ADM Advantage Portfolio. Suite of Grain Marketing Strategies – full range of contracts to build a diversified, risk appropriate portfolio.
Farm Data Payment: ADM offers growers per acre payment for field data.

Appendix 4.2.3 DAIRY Pasture management, robotics, animal health, genetics

CASE STUDIES	COMPANY

DAIRY	CALVING SENSORS	9. MOOCALL	Moocall connecting you to your animals
DAIRY	COW HEAT SENSORS	10. SILENT HERDSMAN	Afimilk Silent Herdsman
DAIRY	COW HEALTH SENSORS	11. CONNECTERRA	Connecterra
DAIRY	FACIAL RECOGNITION	12. CAINTHUS	cainthus
DAIRY	GENOMIC ANALYSIS	13. CRV - HerdOptimizer	CRV
DAIRY	GENOMIC TESTING	14. TL BIOLABS	TL Biolabs
DAIRY	FIND MY FARMER TRACEABILITY	15. ORGANIC VALLEY FIND MY FARMER	ORGANIC VALLEY
DAIRY	BLOCKCHAIN	16. PROVENANCE	PROVENANCE

DAIRY CASE STUDY 1: Calving Sensors

10. MOOCALL
www.moocall.com
Founded: 2014
Type: Private company
Investor: Non-equity assistance
Headquarters: Dublin, Ireland
Geographical coverage: Global 30 countries
Industries served: Dairy

Company Overview: Moocall Calving Sensors measure contractions and predict when your cow will give birth.

DAIRY CASE STUDY 2: Cow Heat Sensors

11. SILENT HERDSMAN
Founded: 1977
Type: Private company
Headquarters: Kibbutz Afikim, Israel
Geographical coverage: more than 50 countries

Product: RFID and sensors for dairy cow health
Industries served: Dairy and beef

Company Overview: Afimilk Ltd. manufactures computerised systems for the modern dairy farm and for herd management. Afimilk introduced the world's first electronic milk meter, first pedometer to monitor cows, first dairy farm management software, first online milk analyser (AfiLab). Farm managers can improve performance and maximise efficiency to increase profits.

Product: **Afimilk Silent Herdsman** Acquired February 2016 from UK Dairy Technology ($4.3M Invested). Neck worn sensor delivers predictive analytics for dairy and beef farmers to improve herd performance, business efficiency and animal welfare. Silent Herdsman offers an illness health alert system, upgraded fertility management providing vet reports, segment specific herd management options, and mobile application. **Other Products**: AfiAct II Leg Tag based on the cow's rest time, AfiAct II for Stanchion Barns, and also an automatic Calving Alert Service.

DAIRY CASE STUDY 3: Cow Health Sensors

12. CONNECTERRA
www.connecterra.io
Founded: 2014
Type: Private company
Investment: $1.8M Seed (May 2016)
Headquarters: Amsterdam, Netherlands
Geographical coverage: Global
Product: RFID and sensors for dairy cow health
Industries served: Dairy

Company Overview: Build devices and creates algorithms in the cloud that provide detection and prediction of real-world events that will enable the industrial Internet of Things.

Product: Ida – The Dairy Farming Assistant Health tracking dairy cow platform uses machine learning and sensor hardware we are able to predict behaviour patterns in dairy farm animals which will help detect disease, predict optimal estrus cycles and improve dairy production.

DAIRY CASE STUDY 4: Facial Recognition

13. CAINTHUS
www.cainthus.com
Founded: 2015
Type: Private company
Headquarters: Dublin, Ireland
Geographical coverage: Ireland; Ottawa, Ontario, Canada; and San Francisco, California, USA
Industries served: Crops and livestock (dairy and beef)

Company Overview: Machine learning for crops and livestock.

DAIRY CASE STUDY 5: Genomic Analysis

14. CRV – HERDOPTIMIZER
www.crv4all.us
Founded: 2009
Type: Private company
Headquarters: Arnhem, the Netherlands; Madison, Wisconsin, USA
Geographical coverage: Global
Industries served: Dairy, precision breeding, genetics (previously Holland Genetics)

Company Overview: CRV is an online platform that provides directory about dairy herds and sends insights to subscribers. HerdOptimizer is a genetic management program that combines genomic testing, customised breeding goals, careful trait selection, easy-to-use test results, and breeding recommendations to deliver faster and more reliable herd improvement.

DAIRY CASE STUDY 6: Genomic Testing

15. TL BIOLABS
www.tlbiolabs.com
Founded: 2016; launching summer 2017
Type: Private company
Investor: $4M seed (February 2017)
Headquarters: Santa Clara, California, USA
Geographical coverage:
Industries served: Livestock (beef and dairy)

Company Overview: TL Biolabs offers genomic testing, providing farmers information on the health, productivity and fertility of their cows to make breeding decisions. Economical genomic tests for beef and dairy cattle, with free software to deliver actionable results.

DAIRY CASE STUDY 7: Find My Farmer Traceability

16. ORGANIC VALLEY 'FIND MY FARMER'
www.organicvalley.coop/our-farmers/find-your-farmer
Founded: 1988
Type: Cooperative: ~2,000 family farmers
Headquarters: La Farge, Wisconsin, USA
Geographical coverage: USA (36 states), Canada, Australia and England
Industries served: Dairy, soy, cattle, meat processing

Company Overview: Organic Valley is a cooperative of farmers producing milk, cream, yogurt, butter, cheese, soy, sour cream, eggs, juice and meat products. Brands: Organic Valley and Organic Prairie. Pioneering cooperative (CROPP Cooperative) owned and guided by family farmers - almost 2,000 of them in 36 states, Canada, Australia and England.

Appendix 4.2.4 PORK Feed conversion, animal production efficiency

CASE STUDIES		COMPANY	
PORK	SOW SENSORS	17. SWINETECH	
PORK	BARN MANAGEMENT	18. MTECH SYSTEMS	
PORK	NITROGEN TRACKING	19. SMITHFIELDGRO + ADAPT-N	

PORK CASE STUDY 1: Sow Sensors

17. SWINETECH
www.swinetech.co
Founded: August 2015
Type: Private company
Investment: $1.3 M
Headquarters: New Sharon, Iowa
Geographical coverage: US market
Industries served: Pork

Company Overview: Develops a monitoring system that analyses the temperature and bio-metric information to detect when a piglet is in peril.

PORK CASE STUDY 2: Barn Management

18. MTECH SYSTEMS
www.mtech-systems.com
Founded: 1996
Type: Private company acquired by Munters Group
Revenue: ~$20M
Headquarters: Atlanta, GA
Geography: 20 Countries: US, Brazil, Mexico
Industries served: Broilers, layers, turkeys, ducks, sows and hogs

Company Overview: MTech's insight and intelligence applications equip poultry and swine producers to utilise comprehensive data in each segment of production to analyse to maximise profits. MTech has set the industry standard in enterprise data solutions for all aspects of the live operations cycle.

Product: Integrated solution covering all phases from genetics to finish product.

PORK CASE STUDY 3: Nitrogen Tracking

19. SMITHFIELDGRO PROGRAM + AGRONOMIC TECHNOLOGY CORPORATION [ADAPT-N]

www.adapt-n.com

Founded: 2013 (Cornell University tech transfer)

Type: Private company

Investment: Funds from Cornell University, USDA-NIFA Special Grants on Computational Agriculture (US Rep. Maurice Hinchey-NY) and the Agricultural Ecosystems Program (US Rep. Maurice Hinchey-NY), Northern New York Agricultural Development Program, a USDA-NRCS Conservation Innovation Program, New York Farm Viability Institute, International Plant Nutrition Institute, Walton Family Foundation, MGT Envirotec, Environmental Defense Fund.

Headquarters: New York, New York, USA

Industries served: Corn producers, meat processing, pork

Products: Adapt-N – nitrogen management solution

Company Overview – SmithfieldGro: SmithfieldGro program, which provides agronomy resources and tools to help farmers optimise their fertiliser application and improve soil health.

Company Overview – Agronomic Technology Corp. (Adapt-N): Adapt-N, an independent recommendation platform manages nitrogen reduction challenges in crop production by modeling soil, water, fertiliser and field management activities. The solution leverages science and data to deliver large-scale, field-specific solutions to enable the trade-off between financial and environmental performance. It is NutrientStar Rated by EDF.

Appendix 4.2.5 EGGS Remote sensing, animal health, feed, electricity, shed monitoring

CASE STUDIES		COMPANY
EGGS	LAYER HEALTH SENSOR	20. DR. MICHAEL TOSCANO, UNIVERSITAT BERN
EGGS	PRINTING - TRACEABILITY	21. MARKEM IMAJE

EGGS CASE STUDY 1: Layer Health Sensor

20. DR. MICHAEL TOSCANO, UNIVERSITAT BERN

www.tierschutz.vetsuisse.unibe.ch/about_us/personnell/dr_toscano_michael_j/index_eng.html

Founded: 2016

Type: Research

Headquarters: Bern, Switzerland

Geographical coverage: US
Industries served: Poultry

Company Overview: Optimising laying hen feeder design, positioning and bird density to maximise bird welfare and production.

EGGS CASE STUDY 2: Printing – Traceability

21. MARKEM-IMAJE
www.markem-imaje.us
Founded: 1982
Type: Traceability solutions and printing products
Revenue: $7.5B [Dover – parent company]
Employees: 29,000 total; 3,000 at Markem Imaje
Headquarters: Switzerland
Geographical coverage: Global
Industries served: Dairy, eggs, dry beverages, fresh fruits and vegetables, fresh meat, poultry products, dehydrated foods, biscuits and confectionery

Company Overview: Markem-Imaje is a world manufacturer of product identification and traceability solutions, offering a full line of reliable and innovative inkjet, thermal transfer, laser, print and apply label systems. Markem-Imaje delivers fully integrated solutions that enable product quality and safety, regulatory and retailer compliance, better product recalls and improved manufacturing processes.

Appendix 4.2.6 FISHERIES AND AQUACULTURE Regulation, geo-positioning data, sustainability, provenance

CASE STUDIES		COMPANY	
FISHERIES AND AQUACULTURE	NET CAMERAS	22. SMARTCATCH	SmartCatch
FISHERIES AND AQUACULTURE	FEEDERS	23. AQUACO FARMS	AQUACO FARMS
FISHERIES AND AQUACULTURE	FEEDERS	24. eFISHERY	eFishery
FISHERIES AND AQUACULTURE	BLOCK CHAIN & PROVENANCE	25. PROVENANCE	PROVENANCE

FISHERIES AND AQUACULTURE CASE STUDY 1: Net Cameras

22. SMARTCATCH

www.smart-catch.com
Founded: 2012
Type: Private company
Headquarters: Palo Alto, California, USA
Geographical coverage:
Industries served: Commercial fishing
Company Overview: SmartCatch focuses on sustainable commercial fishing practice to maximise profits and reduce waste by minimizing catching and destruction of non-target fish.

FISHERIES AND AQUACULTURE CASE STUDY 2: Feeders

23. AQUACO FARMS
www.aquacofarms.com
Founded: 2015
Investment: $1.75M
Headquarters: Ft. Pierce, Florida, USA
Geographical coverage: Farm in Florida
Industries served: Aquaculture - fresh fish (Florida Pompano)
Company Overview: High-tech commercial aquaculture facility changing the way seafood is sourced and purchased with a business model that focused on sustainability and leverages sensors Internet of Things (IoT), to reduce costs and optimize operational efficiency.

FISHERIES AND AQUACULTURE CASE STUDY 3: Feeders

24. eFISHERY
Founded: 2013
Type: Private company
Investment: Undisclosed Amount
Headquarters: Bandung, Jawa Barat, Indonesia
Geographical coverage: Southeast Asia, India
Industries served: Aquaculture, agriculture technology, hardware and software creation, design and manufacturing, and Internet of Things
Company Overview: eFishery real-time fish and shrimp monitoring and food feeding device.

FISHERIES AND AQUACULTURE CASE STUDY 4: Block Chain & Provenance

25. PROVENANCE
www.provenance.org
Founded: 2013
Type: Not-for-profit
Investment: $800K
Headquarters: UK

Geographical coverage: Global
Industries served: Supply chains including food
Company Overview: The Project Provenance platform creates and fosters open and accessible information about products to enable consumers to be informed and support sustainability through the things we choose to buy. Provenance believes companies like them can and should operate both to succeed as a business and in service to local and global communities.

Appendix 4.2.8 COTTON Weather, robotics, efficient inputs – water, nitrogen

CASE STUDIES		COMPANY	
COTTON	NOZZLE BY NOZZLE CONTROL	26. TRIMBLE PRECISION IRRIGATION	
COTTON	SOIL MICROBES + PLANT GENETICS	27. INDIGO	
COTTON	TRACE FROM FIELD TO GARMENT	28. BCI + BAYER E3 COTTON	
COTTON	TRACKER	29. MADE-BY MODE TRACKER	

COTTON CASE STUDY 1: Nozzle-by-Nozzle Control

26. TRIMBLE PRECISION IRRIGATION
www.agriculture.trimble/precision-ag/solutions/irrigation
Founded: 1978
Type: Public, NASDAQ: TRMB
Revenue: $3.1B
Headquarters: Sunnyvale, California, USA
Geographical coverage: Global 120 countries
Industries served: Agriculture, construction, buildings
Product: Irrigate-IQ
Company Overview: Trimble provides global positioning systems and robotic optical surveying instruments.

COTTON CASE STUDY 2: Soil Microbes + Plant Genetics

27. INDIGO
www.indigoag.com
Founded: 2014

Type: Private company
Investment: $156M in 3 rounds from 2 investors
Most recent funding: $100M Series C (July 2016)
Headquarters: Boston, Massachusetts, USA
Geographical coverage: US
Industries served: Cotton, wheat, rice, corn, and soybeans
Product: Machine learning for microbe management for water efficiency
Company Overview: Indigo searches for beneficial microbe pairing with the plant. Apply algorithms and machine learning to plant database to predict which microbes are most beneficial to the plant's health. The products complement the plant's natural processes to improve health and development across each phase of life, while boosting crop yields.

COTTON CASE STUDY 3: Trace from Field to Garment

28. BAYER E3 COTTON and BETTER COTTON INITIATIVE
www.e3cotton.us and http://bettercotton.org/
Founded: 2005
Type: Not-for-Profit
Headquarters: Leverkusen, Germany [Bayer]; Geneva Switzerland and London, UK [BCI]
Geographical coverage: Global
Industries served: Cotton growers
Products: eBetter Cotton Initiative; Bayer e3cotton production aided by Fieldprint ® Calculator
Program Overview: The Better Cotton Initiative is a global program focused on sustainably grown cotton. As a BCI partne, all e3 (equitable, economical, environmental) cotton originates with Bayer CropScience's Certified FiberMax® or Authentic Stoneville® seed that can be traced from the farm to the gin through the merchant, mills, and retailer to the consumer. e3 cotton growers agree to certification, verification and independent audits by Wakefield Inspections in the areas of water efficiency, pesticide usage and soil fertility management, greenhouse gas reduction, energy conservation, worker health and safety and identity preservation.

CASE STUDY 4: Tracker

29. MADE-BY MODE TRACKER
www.made-by.org
Founded: Over 10 years ago
Type: Not-for-profit organisation
Investment: Self-funded
Headquarters: London, UK
Geographical coverage: Italy, Germany, UK
Industries served: Fashion brands
Products: MODE Tracker
Company Overview: An award-winning not-for-profit organisation, acting to improve

environmental and social conditions within the fashion industry.

Appendix 4.2.11 HORTICULTURE Storage, supply chain, labour, water laser cutters

CASE STUDIES		COMPANY	
HORTICULTURE	SOIL TESTS	30. TRACE GENOMICS	
HORTICULTURE	SENSOR NETWORKS	31. SEMIOS	
HORTICULTURE	MACHINE DATA	32. PROSPERA	
HORTICULTURE	LABOUR PAYROLL	33. i-FARM HARVEST CLOCK	

HORTICULTURE CASE STUDY 1: Soil Tests

30. TRACE GENOMICS
www.tracegenomics.com
Founded: 2015
Type: Private company
Investment: $4M Seed (July 2016)
Headquarters: San Francisco, California, USA
Industries served: Agriculture: lettuce, strawberries, nuts, orchards, vineyards and also some corn, soy, and wheat growers
Company Overview: Trace Genomics (previously PathoGn, Inc.) uses genomics and machine learning to provide soil health and disease recommendations that optimise yield, a '23andMe' for soil health. They use molecular assay for soil and seed-borne pathogens enables affordable detection of hundreds of pathogens and beneficial organisms simultaneously. Their assay is based on genetic sequencing technology to identify and quantify specific strains.
Product: 'Custom soil health kit' for farmers using machine learning and genomics testing.

HORTICULTURE CASE STUDY 2: Sensor Networks

31. SEMIOS
www.semios.com
Founded: 2010
Type: Private company
Investment: $9M
Headquarters: Vancouver, BC, Canada
Geographical coverage: North America (California)
Industries served: Vineyards, tree fruit and tree nut

Company Overview: Semios is a precision farming Internet of Things (IoT) platform for tree fruits, nuts and grapes. Semios provides a proprietary system of in-crop wireless networks coupled with remote sensors, real-time pest monitoring and variable rate biological pest control. This information is provided to the grower in an intuitive interface to reduce inputs and increase the crop quality. In May 2017, 150,000 sensors reported every 10 minutes from every acre of some of the largest tree fruit and nut farms in North America, measuring weather, leaf wetness, soil moisture, insect trap counts and other information that farmers need.

HORTICULTURE CASE STUDY 3: Machine Data

32. PROSPERA
www.prospera.ag
Founded: 2014
Type: Private company
Investment: ~$22M in 2 rounds from 4 investors
Headquarters: Tel Aviv, Israel
Geographical coverage: Israel, Europe, Mexico, USA
Industries Served: Large farms produce (produce growers for Walmart, Tesco, Sainburys, Aldi)
Products: Farm software

Company Overview: Using data analytics, computer vision and artificial intelligence, Prospera collects, digitises and analyses vast amounts of agricultural data and optimises production.

HORICULTURE CASE STUDY 4: Labour Payroll

33. i-FARM HARVEST CLOCK
www.i-farm/payroll
Founded: February 2017
Type: Private company
Investment: Unknown
Headquarters: Seattle, WA
Geographical coverage: US
Industries served: Growers requiring mostly labour to harvest crops
Products: Harvest Clock

Company Overview: i.FARM is a software as a service company that provides management information systems to specialty crop farmers.

Product: Harvest Clock tracks labour for hand harvested crops of all sizes. Each employee is assigned a QR Code that is scanned by the iPhone camera. After the employee is scanned, you tap the number of boxes picked and save the record. If you harvest into bins and have bin tickets you can scan that as well. An optional receipt printer will print the employee a receipt. Cellular connectivity sends the tickets immediately into secure servers in real time. The tickets are instantly transformed into real time reports that allow you to monitor your harvest up to the minute. Export the harvest data into multiple formats that can be used for payroll.

Fraud Prevention: Ensure proper payment for work done. Harvest Clock uses the connected server to help prevent payroll fraud in the field. If one payroll clerk notices a quality problem, or suspects duplicate entries, it sends a notice to all the other payroll clerks using Harvest Clock allowing them to work together to keep your records accurate and fair.

Appendix 4.2.12 WINE Climate, irrigation, harvest, scheduling

CASE STUDIES		COMPANY	
WINE	VARIABLE RATE DRIP IRRIGATION	34. NETAFIM	NETAFIM™
WINE	LIDAR 3D VINEYARD MAPPING	35. AGERPOINT	AGERpoint

WINE CASE STUDY 1: VARIABLE RATE DRIP IRRIGATION

34. NETAFIM – 3RD GENERATION NETAFIM MODULAR IRRIGATION

www.netafim.com/crop/wine-grapes

Founded: 1965
Type: Private company
Revenue: $3.1B
Employees: 4,300
Headquarters: Tel Aviv, Israel
Geographical coverage: Global 110 countries
Industries served: Agriculture, greenhouse, landscape, mining

Company Overview: Global leader in smart irrigation solutions, Netafim pioneered the drip revolution, creating a paradigm shift toward low-flow agricultural irrigation. Today, Netafim provides diverse solutions – from state-of-the-art drippers to advanced automated systems – accompanied by expert agronomic, technical and operational support.

WINE CASE STUDY 2: X-Ray for Grape Bunches

35. AGERPOINT - LIDAR FOR VINEYARDS

www.agerpoint.com

Founded: 2012
Type: LIDAR Technology
Investment: $2.5M
Headquarters: Orlando, FL
Geographical coverage: US, Stated "Going Global"
Industries served: Viticulture, citrus, orchards.
Product: AGERmetrix web interface; Grovetracker – Canopy; Harvesttracker - Crop

Company Overview: AGERPoint sensor suite uses survey grade RTK GPS with a machine vision camera delivering LIDAR data to size crop, fruit and canopy to project yield.

Appendix 4.2.13 SUGAR Geospatial harvest maps, mill performance, productivity + delay

CASE STUDIES		COMPANY	
SUGAR	PRODUCTIVITY + DELAY MANAGEMENT	36. TRIMBLE SUGARCANE SOLUTIONS	

SUGAR CASE STUDY 1: Productivity Plus Delay Management

36. TRIMBLE SUGARCANE SOLUTIONS
www.agriculture.trimble.com/precision-ag/applications/sugarcane
Founded: 1978
Type: Public, NASDAQ: TRMB
Revenue: $3.1B
Employees: 5,001-10,000 employees
Headquarters: Sunnyvale, California, USA
Geographical coverage: Global 120 countries
Industries served: Agriculture, construction, building
Product: Trimble Sugarcane Solutions
Company Overview: Sugarcane planting solutions from Trimble combine advanced precision agriculture technologies and tools to help you optimise your planting capabilities, ensure consistency across your farm, and increase profitability.

Appendix 4.2.14 FORESTRY Processing efficiency, paper, timber, sustainable, preservation, labour

CASE STUDIES		COMPANY	
FORESTRY	FOREST INVENTORY	37. SILVIATERRA	
FORESTRY	PHODAR FOREST MONITOR	38. EAGLE DIGITAL IMAGING	

FORESTRY CASE STUDY 1: Forest Inventory

37. SILVIATERRA

www.silviaterra.com/bark
Founded: 2010
Type: Private company
Headquarters: San Francisco, California, USA
Geographical coverage: Global
Industries served: Forest inventory, biometrics, GIS, cloud computing, mobile, remote sensing
Company Overview: A small team of foresters, biometricians, and programmers dedicated to expanding our understanding of forests and strengthening our ability to manage these complex and vital ecosystems. Combining expertise in biometrics with the latest developments in remote sensing, big data, cloud computing, and mobile, SilviaTerra solves forest inventory problems with a fraction of the time and cost of conventional cruising. With millions of acres already relying on SilviaTerra technology, our tools have a proven seven-year track record.

FORESTRY CASE STUDY 2: PhoDAR Forest Monitor

38. EAGLE DIGITAL IMAGING- PhoDAR FOR FORESTRY
www.eagleimaging.net
Founded: 2006
Type: Imaging services
Headquarters: Corvalis, OR
Geographical coverage: Pacific Northwest; California
Industries served: Forestry, agriculture, mining, natural resources, municipal
Product: Imaging services including forest inventory; harvest depletion; canopy and density analysis and young stand assessments; PhoDAR and 3D modeling services
Company Overview: Eagle Digital provides aerial imaging for millions of acres of forestry ownership every year. With many levels of resolution; colour-infrared or 4-channel images. have been providing services to the largest forestry companies in the US for over a decade.

Appendix 4.2.15 RICE | CHICKEN MEATS | BEES Efficient water and nitrogen, animal [egg] health, bee health

CASE STUDIES		COMPANY	
RICE	SUSTAINABILITY DATA	39. SYNGENTA AGRIEDGE	
CHICKEN MEATS	POUTRY OPERATION MANAGEMENT	40. POULTRICS	
BEES	REMOTE (BEE) HIVE MONITORING	41. ARNIA	

RICE CASE STUDY 1: Sustainability Data

39. SYNGENTA AGRIEDGE
www.agconnections.com
Founded: 1998
Type: A wholly owned subsidiary of Syngenta
Headquarters: Murray, Kentucky, USA
Geographical coverage: US
Industries served: Sustainability
Product: Farm management software

Company Overview: The AgriEdge program has been on US farms since 2002. Enrollment in AgriEdge provides growers with data and record-keeping access through AgConnections Land.db®. The software captures all information associated with a farm, including yield, timing of sprays, compliance reporting, as well as input costs and return on investment. It then tracks, measures and examines each acre to see if it's profitable and/or sustainable.

Product: Rice Growers Compensated for Tracking Sustainability Metrics Working with Arkansas rice growers to track water and nitrogen management for sustainably grown in the USA standard set by C-AGG and managed through Land.db. Growers are compensated on achieving different documented levels of sustainability. The system will alert growers as to the next activity or program in which they can participate to reach the next compensation level.

CHICKEN MEATS CASE STUDY 1: Poultry Operation Management

40. POULTICS
www.poultrics.com
Founded: 2015
Type: Private
Financing: This project is funded by FRACTALS (Future Internet Enabled Agricultural Applications, FP7 project No. 632874), under funding framework of the European Commission
Headquarters: Europe
Geographical coverage: European Union
Industries served: Poultry
Product: Rural Poultry Management System

Company Overview: The 'Poultrics' Rural Poultry Management System (RPMS) is a cloud-based solution that addresses the technical, operational and administrative obstacles that hinder the development and sustainability of pasture/free-range poultry. The system tackles business critical issues such as feed conversion, water consumption, desegregation of consecutive fowl generations, strict nurturing times, genealogical traceability, thorough documentation, stock and warehousing of fowl products, financial statistics and analyses, etc. The RFID based identification, traceability and physical control through standard interfaces to external hardware, bring unparalleled levels of individual fowl handling, optimising the workforce load and greatly reducing the time spent on mundane and manual labour intensive tasks.

BEES CASE STUDY 1: Remote (Bee) Hive Monitoring

41. ARNIA – REMOTE (BEE) HIVE MONITORING
www.arnia.co.uk
Founded: 2009, launched its first products in October 2013
Type: Private company
Headquarters: UK
Geographical coverage: More than 25 countries
Industries served: Beekeepers, bee researchers and the crop protection and agritech industries
Products: Remote hive monitoring
Company Overview: Since 2011, Arnia has been tracking and monitoring behive behavior with the largest network of installed monitors. Arnia combines hive acoustics monitoring with other parameters such as brood temperature, humidity, hive weight and apiary weather conditions. The system can monitor and interpret the sound of a bee colony to assess colony behaviour, strength and health. Hive data can be accessed remotely from any Internet-enabled device in any web browser.

Appendix 4.2.16 IMAGERY

CASE STUDIES		COMPANY	
IMAGERY	CROP FORECASTING	42. DESCARTES LABS	Descartes Labs

IMAGERY CASE STUDY 1: Crop Forecasting

42. DESCARTES LABS
www.descarteslabs.com
Founded: 2014
Type: Private
Investment: ~$38.28M in 4 rounds from 11 investors
Most Recent Funding: $30M Series B (August 2017)
Headquarters: Santa Fe, New Mexico, USA
Geographical Coverage: Brazil, Indonesia, Malaysia, Russia, United States
Industries Served: Corn, palm oil, soy, wheat, specialty crops
Product: Imagery analytics for research and crop forecast
Company Overview: Descartes Labs, a research-and analytics-driven company uses machine learning to analyse years of scientifically calibrated satellite imagery (has access to a massive archive of satellite imagery sourced from NASA, the European Space Agency (ESA), and other ‘commercial constellations’ and the archive goes back decades) the company wants to track everything that’s changing on Earth’s surface – from deforestation to transportation to

agriculture – where they can successfully predict changes in crop health and yield.

Appendix 4.2.16 SENSORS, Potatoes

CASE STUDIES		COMPANY	
SENSORS	POTATO SENSORS + SW	43. DACOM	
SENSORS	IOT SENSOR NETWORK	44. ZEDI	

SENSORS CASE STUDY 1: Potato Sensors + SW

43. DACOM INTELLIGENT SOLUTIONS
www.dacom.farm
Founded: 1987
Type: Private company
Headquarters: Emmen, Netherlands
Geographical Coverage: 50 countries
Industries Served: Agriculture, smart farming and irrigation
Product: Dacom Farm Intelligence

Company Overview: Dacom Farm Intelligence platform is the global market leader, for potato growers. Dacom allows growers to optimise crop quality with sensor equipment, data driven software and advisory services. Capabilities include crop recording, weather forecasts, soil moisture sensor and irrigation management and disease management solutions.

SENSORS CASE STUDY 2: IoT Sensor Network

44. ZEDI
www.zedi.com
Founded: 1987
Type: Privately-held after a management buy-out in February 2014
Product: Multi-utilities integrated oil and gas
Headquarters: Calgary, Alberta, Canada
Geographical coverage: Global
Industries served: Oil and gas, "Internet of Things", agriculture, smart dities and microgrids

Company Overview: Oil and gas technology services company focused on field production operations. Through software and automation backed by expert services – they have moved from oil and gas to supporting Monsanto research fields with the intention to deliver services direct to farm operations.

Value Proposition: Geek squad for the farm.

Appendix 4.2.17 TRACTOR CONTROL

CASE STUDIES		COMPANY	
TRACTOR CONTROL	AUTONOMOUS CONTROL	45. DOT	
TRACTOR CONTROL	LOW COST MOBILE APP GPS	46. EFARMER	
TRACTOR CONTROL	OPTIMAL FIELD PATH	47. JCA ELECTRONICS - FLIGHTPATH	

TRACTOR CONTROL CASE STUDY 1: Autonomous Control

45. DOT
www.seedotrun.com
Founded: 2014
Type: Private company (sister company SeedMaster Manufacturing)
Geographical coverage: Canada
Industries served: Autonomous implements
Product Overview: DOT is a diesel-powered, hydraulically driven platform equipped to carry any implement designed as DOT Ready™. Four lift-points lift the implement directly onto DOT's U-shaped structure, enabling DOT and the implement to become one unit. DOT then functions as a power platform that is programmed to move and do specific jobs autonomously or by remote control. DOT's short- and long-range sensors make the platform more accurate and attentive than any human. DOT constantly updates itself with images of the physical world, processes and uses the data to make decisions. DOT sends alerts to farmers if it is unsure how to proceed. Working for farmers, DOT completes tasks autonomously and enables farmers to spend more of their time focusing on the overall farm operations.

TRACTOR CONTROL CASE STUDY 2: Low Cost Mobile App GPS

46. EFARMER
www.efarmer.mobi and www.effectivefarmer.com
Founded: 2010
Type: Private company
Headquarters: Noordwijk, Netherlands
Geographical coverage: EU
Industries served: Farms
Product: FieldBEE GPS, activity tracking

Company Overview: Efarmer designs and develops farm management software that offers field records, guidance, team management and tractor navigation solutions, 'Tom Tom for tractors.'

TRACTOR CONTROL CASE STUDY 3: Optimal Field Path

47. JCA ELECTRONICS - FLIGHTPATH
www.jcaelectronics.ca/precision-farming
Founded: 2002
Type: Private company
Headquarters: Winnipeg, Manitoba, Canada
Geographical coverage: Global
Industries served: Implement manufacturers
Product: FlightPath

Company Overview: JCA FlightPath is a set of software libraries that can be integrated into customised solutions for implement manufacturers, but provide many of the complex functions needed in precision farming applications. These libraries use tablet and RTK GPS systems. With the decreasing costs of these technologies, there is a growing possibility of applying precision farming to new applications, and introduce an alternative to traditional solutions.

Appendix 3. Three case studies of US based decision agriculture products

The following three case studies were conducted at the beginning of the P2D project to provide an overview of how value chains can be impacted by decision agriculture. The businesses were selected on the basis that they all provide products which are based around a farm management platform however the way that the data that is entered on the platform is used for post farmgate value chain activities is varied for each example.

- HarvestMark – Traceability
- Agrian – Regulatory compliance
- Farmers Business Network – Benchmarking and farm input supplies.

The case studies were compiled for AFI by Sarah Nolet from AgThentic.

Case Study: HarvestMark

Executive Summary

HarvestMark is a platform solution that includes on-product barcodes and a backend database that generates reports. The platform comprises four distinct products: PTI & Item Level Traceability, DC Insights, Retail Insights, and Connect. HarvestMark provides traceability solutions from case level to individual product level for all participants along the supply chain, including large and small growers, wholesalers, and retailers. HarvestMark provides traceability information by putting a barcode on packaging, and collecting all data associated with the barcode as it travels to the consumer. HarvestMark collects and analyzes four types of data: (1) traceability; (2) quality (e.g., age, appearance, freshness); (3) operational (e.g., delivery, dwell, handling, merchandising); and (4) consumer data (e.g., taste, experience, value).

With these products, HarvestMark makes the supply chain more efficient by helping all participants to manage recalls, monitor for quality, track everything associated with a product (e.g., quality, location), and ultimately collect insights from end consumers, who can scan, review, and provide feedback. Specifically, HarvestMark helps brands to make data-driven decisions and ultimately improve their top lines, and helps growers to prevent and manage recalls and adapt production to meet consumer demand.

HarvestMark was originally created by YottaMark Inc., a company founded in 2005, which was acquired by Trimble, a $2 billion hardware company with a significant presence in agriculture, in late 2014. HarvestMark is located in Sunnyvale, California, and has a global customer base, including North America, Europe, China, South America, and Australia.

Background

Company History

Elliott Grant founded YottaMark Inc., the company that developed the HarvestMark platform, in 2005 in Redwood City, California. Mr. Grant previously held titles such as VP of Operations, and engagement manager at McKinsey & Co., and received his PhD in Engineering from Cambridge University.

The original idea for the company was to provide technology that would enable traceability for brand protection and anti-counterfeit. Their solution was for many industries, such as computer hardware and electronics, rather than the food and agriculture industry exclusively. The company provided a serial number for each product using random numbers, kept a database of product movements, and used this information to prevent counterfeiting. They had success, such as helping Intel protect their network cards.

The company soon found that there were more attractive opportunities in food and agriculture, especially for perishables where there were concerns for public safety and high costs of recalls. The team was also compelled by examples of misattributed recalls in the food industry, and the subsequent negative effects. When a food safety issue occurs, for example in a jar of salsa, the culprit may be identified as the tomatoes from a certain producer. That producer must then recall all of his/her tomatoes, at significant cost. Unfortunately, it often happens that another item, say jalapenos, were in fact responsible; however, by the time this is discovered, the tomato producer may already be out of business. YottaMark saw an opportunity: with better systems to understand what happens along the supply chain and where products originate from, these issues can be avoided. HarvestMark was then developed to provide traceability solutions for the food system.

Around the same time, in 2008, the produce industry launched an industry-led initiative to improve traceability along the food supply chain. Ultimately, this initiative, the Product Traceability Initiative[i], produced standards for implementing case-level electronic traceability. HarvestMark contributed IP to the development of these standards, and helped to encourage widespread adoption.

The company soon began to focus exclusively on food system traceability solutions under the HarvestMark platform. In 2013, they acquired ShopWell, a consumer-driven application to help retailers access anonymous data about consumer decisions.

At the end of 2014, HarvestMark was approached and ultimately acquired by Trimble. Trimble, a US$2Billion company, is a significant provider of hardware and software data collection and analysis solutions for many industries, including agriculture.

Company Structure

HarvestMark is currently a division of Trimble. When HarvestMark was acquired in 2015, Charlie Piper, YottaMark CEO, left the company. Dan Sun, who led the acquisition effort, took over as President of the HarvestMark division.

HarvestMark is located in Sunnyvale, California and currently has around 50 employees.

HarvestMark has 37 U.S. and international patents around traceability and quality protection, which creates a significant barrier to entry against potential competition.

Products and services

The HarvestMark platform enables traceability solutions from case level, down to individual product level (e.g., a melon or container of berries). The platform has four distinct products: PTI & Item Level Traceability, DC Insights, Retail Insights, and Connect.

With these products, HarvestMark provides solutions for all participants along the supply chain to manage recalls, monitor for quality, track everything associated with a product (e.g., quality, location), and ultimately collect insights from end consumers, who can scan, review, and provide feedback. HarvestMark is also able to aggregate and mine the data to look at trends around best practices, what consumers like, and where aspects of their operations are working (or not). HarvestMark then provides this information to their clients- brands or growers- who can then make data-driven decisions.

Behind the scenes, the HarvestMark platform is enabled by a barcode that is issued on each product or case. The barcode is tracked throughout the supply chain. Consumers can scan a QR code on the product, and receive and enter information. For example, consumers can review the product and receive coupons or cross-promotions for other related items.

Market Presence

HarvestMark has established a global customer base. They have very good coverage of the U.S. and North America in general, as well as customers, especially growers, in Europe, China, and South America. HarvestMark is not currently in Africa, but is thinking about entering this market.

HarvestMark also has customers in Australia, including growers and retailers. For the retailer customers, such as supermarkets Aldi and Woolworths, HarvestMark offers quality inspection for their incoming produce. Their technology can measure age, freshness, and defects, allowing these retailers to use data to make decisions about accepting or rejecting incoming product.

The HarvestMark technologies can apply to all types of food products; however, perishables and high value products tend to be a better fit, as customers can justify the expense against the cost of a recall or the potential to gain a premium.

The HarvestMark customer base largely comprises growers (90%), including small growers as well as top-of-market, larger brands. 80-90% of HarvestMark's revenue comes from large growers and retailers, as these customers have the resources to pay for more services.

As of 2015, over 3,000 farms and 350 companies were using HarvestMark, comprising a total of over seven billion packages of food[ii].

Future Strategy

HarvestMark has achieved success partially because they offer a solution to food safety regulations and a solution to implementing the PTI's traceability standards. Food safety will always be an issue and an opportunity for HarvestMark, but moving into the future, HarvestMark is looking to capitalise on increasing consumer demand for provenance information.

HarvestMark will also be rolling out a new product in the future: supplier insights. Supplier Insights will be an offshoot of DC Insights, and will allow growers to do Quality Assurance (QA) before sending their products to market. With this product, growers can identify issues before the ship product. This will save money on transportation costs, as well as increase product availability to retailers, who can in turn improve their fulfilment rates and quality metrics.

Use Case: Supply Chain Traceability

The HarvestMark Product Suite

The HarvestMark platform comprises four cloud-based software-as-a-service products: PTI & Item Level Traceability, DC Insights, Retail Insights, and Connect. All products are hosted on Microsoft Azure / AWS. The diagram below illustrates how the different products produce an end-to-end supply chain solution for growers, wholesalers, retailers, and consumers.

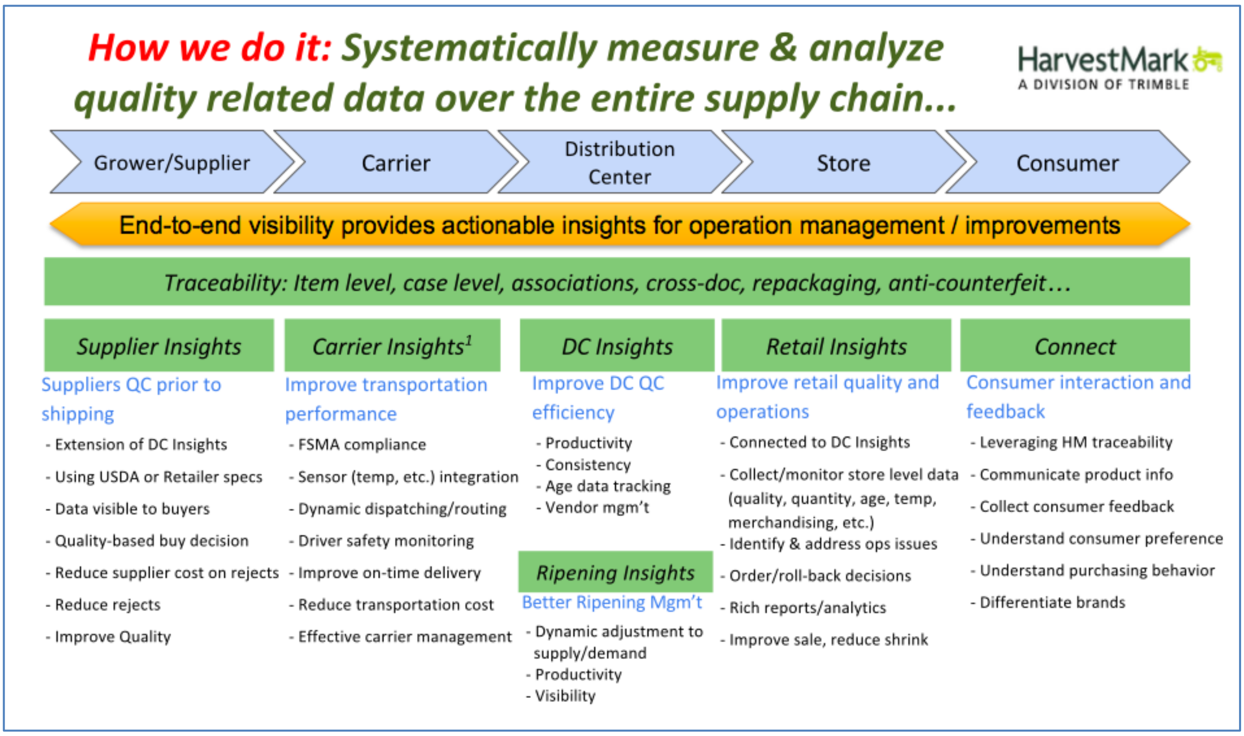


Figure 1: HarvestMark End-to-End Supply Chain Solutions (Source: HarvestMark)

At a high level, HarvestMark collects and analyzes four types of data: (1) Traceability; (2) Quality (e.g., age, appearance, freshness); (3) Operational (e.g., delivery, dwell, handling, merchandising); and (4) consumer data (e.g., taste, experience, value). HarvestMark's four products provide different participants along the supply chain with a custom user experience and entry-point into the data collection and analysis.

PTI & Item Level Traceability

PTI & Item Level Traceability helps participants along the supply chain to comply with Produce Traceability Initiative standards by tracking products throughout the supply chain. Within this product, HarvestMark offers a solution for both product level and item level traceability. In both cases, HarvestMark provides a barcode for the product or item that serves as a unique identifier. Barcodes are placed on the container (e.g., box) or specific item (e.g., melon; carton of berries), respectively. HarvestMark maintains a database of the barcode and its association to a particular company and any additional pertinent information.

Growers and producers, as well as downstream players such as wholesalers and retailers, use the product-level traceability solution. The main use case for this product is to help manage and prevent product recalls. With HarvestMark, growers can identify the specific location a recalled product comes from, and trace all other products from that location back and forth along the supply chain to quickly identify (and recall) all contaminations. One downside of this product is that the line of traceability is "lost" when the container is unpacked and individual items are placed on the retail shelf. For example, as lettuce is unloaded from a package and placed as individual heads of lettuce on the retail floor, provenance information is lost and individual heads can no longer be distinguished.

The item level traceability solution provides essentially the same functionality, but extended to the level of individual items. This product is more expensive, as more barcodes must be issued, and more data (2-3 times more) must be managed and mined for insights. Therefore, this product is often reserved for higher value products (e.g., produce), and the customers of this product are usually brands who have larger budgets. Brands also like this product because it can integrate with HarvesMark's Connect product (see below) to get consumer insights.

The item-level traceability product can collect the following data, some of which can be abstracted from the consumer-facing view:

- Trace and production data:
  - Growing region
  - Farm
  - Harvest and pack date
  - Variety
- Shopper Engagement and Other Content:
  - Marketing Message
  - Survey program
  - Product-centric recipes
  - Handling and storage
  - Nutrition information
  - Shipper story

DC Insights

DC Insights is a mobile application that helps with quality inspection and vendor management. The main customers are retailers and food service companies. DC Insights helps these customers to perform QA inspections of produce by taking pictures and recording defects such as discolouring, decay, and incorrect temperatures. The app can also be used to do cooler walks and manage product quality in real time. Ultimately, the app helps retailers and food services companies decide what to accept and what to pull out of inventory.

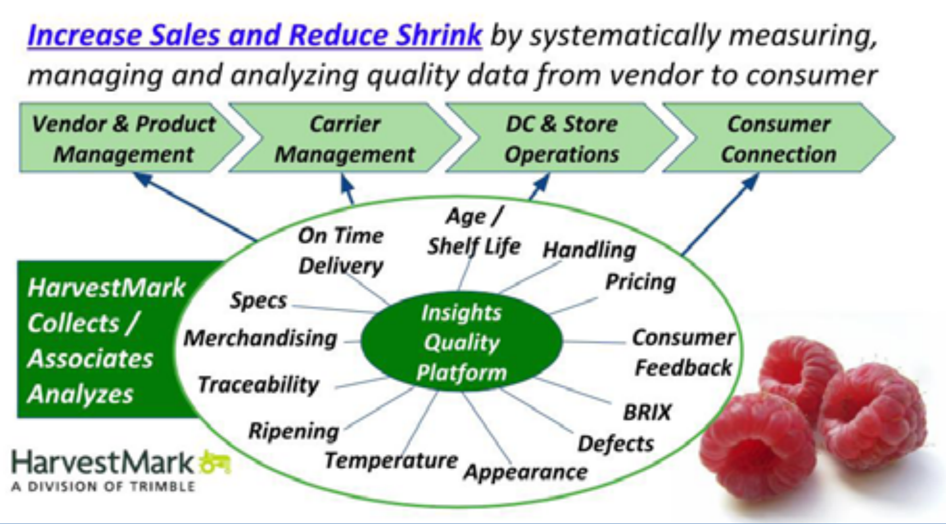
Large growers might also use DC Insights to manage their QA processes. These customers often use DC Insights in conjunction with one of the traceability products described above.

DC Insights is ERP agnostic, meaning it can work with HarvestMark clients' existing software systems.

Retail Insights

The HarvestMark Retail Insights product is a mobile application like DC Insights that is used at the retail level to manage quality inspections. Retail Insights allows retailers to check on-shelf product quality, shelf capacity, and shelf cleanliness. It also supports QA on products: employees can enter data about whether, for example, a head of lettuce has a blemish, or is old, dry, frozen, or ugly.

Figure 2 HarvestMark Value Proposition (source: HarvestMark)



Retail Insights is not as detailed and does not offer as many statistics as DC Insights. However, it does help retailers to solve a huge pain point: paper-based QA systems and out dated data storage systems. Retail Insights replaces paper and pencil systems that are hugely inefficient and often inaccurate.

Connect

The Connect platform is a HarvestMark product that can either be a standalone solution, or be integrated as an addition to the item-level traceability product. In the former case, the main customer is a large retailer that wants to outsource on-floor consumer interaction to technology. For example, some retailers do not have in-store employees who can talk to consumers about products and make decisions about product performance. Connect helps these retailers to perform stock analyses, such as cross-vendor comparisons of inventory turns, price, and consumer impressions, based on data collected from consumers and suppliers. As part of the initial setup for this solution, HarvestMark works with all the retailer’s suppliers to get at QR code onto product labels.

Retailers also benefit because Connect allows HarvestMark to present brand information directly to consumers. For example, consumers can see brand marketing (e.g., recipes, testimonials) and access promotions (e.g. “you’ve just bought strawberries, here’s a coupon for blueberries”). Brands benefit because data-driven insights allow them to provide highly targeted, direct to consumer marketing.

In the background, HarvestMark’s cloud-based database runs queries about products, brands, and producer location. These insights feed back both up and downstream to inform production and purchasing decisions.

Connect can also be used as an add-on to the item level traceability product. In this use case, consumers scan the QR code to see information about the brand, as well as access promotions.

Data and Analytics

HarvestMark manages and mines a large database to provide their customers with data-driven insights. The types of data vary based on the product, but generally include location, variety, quality, temperature, taste, freshness, and all the parties involved along the supply chain.

For all customers, HarvestMark generates and sends a set of common reports that provide insights such as market trends and what happens to your products downstream after they are sold. HarvestMark also employs business intelligence analysts and data experts to mine the data and do custom analyses for customers. These experts work with customers to determine the types of analyses that will be most useful, such as correlations between seasons and quality, or between quality and retail stores.

Different types of customers have different requirements for data collection and analysis. For example, bigger farming operations that have associated brands tend to have their marketing teams work very closely with HarvestMark. Smaller operations, in contrast, still want the data that HarvestMark can provide, but they often cannot afford to spend additional money on deeper insights.

Competition

Traceability is highly desirable along supply chains in many industries in addition to food, and there are technologies and solutions like HarvestMark in other industries (e.g., pharmaceuticals). However, because of the significant domain expertise necessary, it is not easy for companies to provide cross-industry solutions.

Within the food industry in the U.S., HarvestMark has several competitors also providing Product Traceability Initiative compliance solutions. The regulatory-driven environment creates high demand for these solutions, and lowers barriers to entry.

HarvestMark faces fewer competitors in the item level traceability and quality inspection spaces. The former is more complex and requires a deep understanding of brand and industry idiosyncrasies.

Challenges

A big challenge for HarvestMark is the fact that the industry is largely slow to adopt technology. Retailers and farmers are resistant, according to HarvestMark. Reasons for slow adoption include existing mental models, lack of leadership buy-in, or insufficient infrastructure. The challenge may also be organizational: not all companies have cross supply-chain organisational structures that make it easy for everyone involved- from packaging to marketing to decision makers- to buy-in to HarvestMarks' solution.

Data security has not been an issue for HarvestMark. HarvestMark customers have full control of what data they disclose to consumers, and consumers give permission to use their data via opt in when they complete surveys. In most cases, no personal information is collected.

HarvestMark's Impact

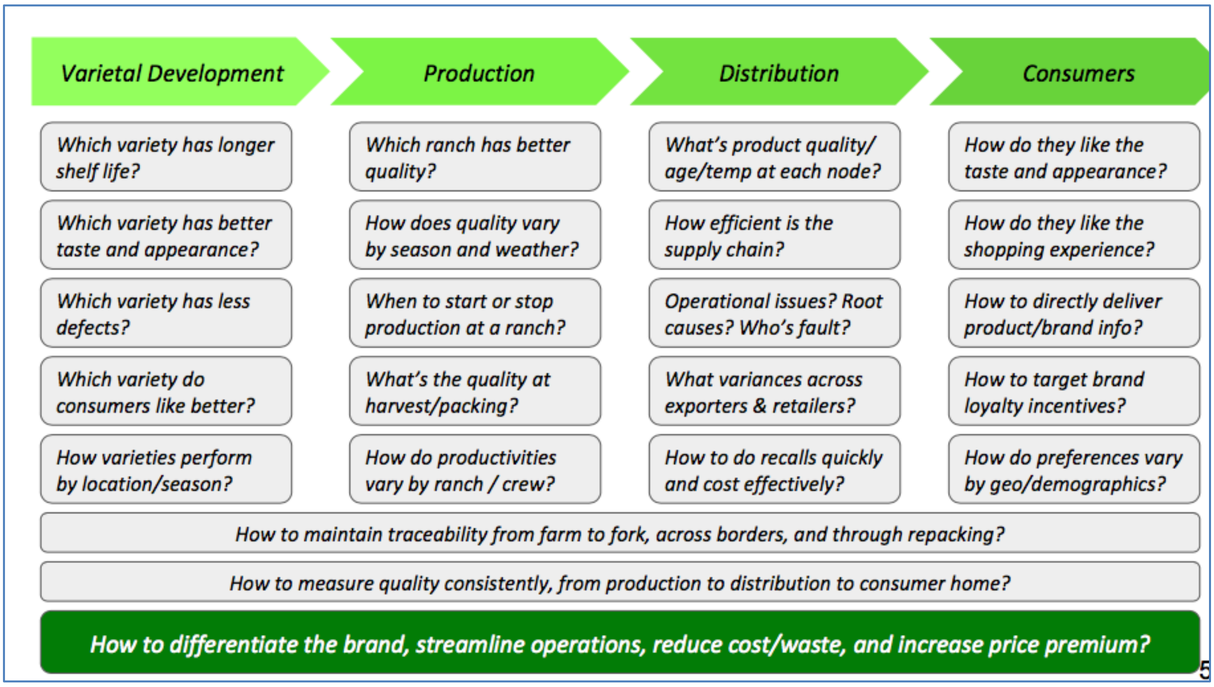
On-Farm Economic and Practice-Change Impact

HarvestMark's products provide several benefits to growers. First, HarvestMark helps growers to prevent, or easily manage, recall events. Preventing recall events can save significant costs growers, as well as help to maintain the value of their brand asset.

Second, and simultaneously, HarvestMark helps growers to be more proactive in their operations by preventing recalls or identifying them much more quickly. Again, this saves money: by controlling quality from the source, growers save on transportation and labour.

HarvestMark can provide these two benefits because their software-as-a-service (SaaS) product captures data that answers key business questions. *Figure 1*, below, depicts these questions across the supply chain from production to consumption.

Figure 3 Key Business Questions for growers (source: HarvestMark)



Finally, given their end-to-end solution with a direct connection to consumers, HarvestMark helps growers to adapt their production to match consumer demand. Not only can growers better meet the growing demand for traceability and provenance, but also, growers can match what, and how, they produce to the desires of the market. For example, HarvestMark gives growers data to inform varietal selection based on in-market performance (e.g., taste, appearance, shelf life, aroma), and to make production decisions based on consumer perceptions of quality and seasonality.

> *"Coupled with Trimble's Connected Farm™ solution, HarvestMark enables producers to make real-time decisions that improve the quality and safety of fresh*

food grown on their farms. By monitoring their quality metrics, producers can ensure they are delivering the highest quality fresh food to the retailer while reducing the likelihood and impact of a foodborne health event. When combined with Trimble's portfolio of Agriculture products, producers can achieve better results through cost reduction and higher income from greater fresh food quality."

- April, 2015 Trimble Media Release[ii]

Broader Economic Impact on the Industry

More broadly, HarvestMark products make the supply chain more efficient for all participants. For example, HarvestMark helps retailers to improve quality and reduce waste. The DC Insights and Retail Insights products provide data to drive decisions about when to reject incoming supply. If a retailer accepts product that they then cannot sell, they incur shrinkage (e.g., wastage), which is costly. Further, by increasing their rejection rate based on data, retailers can improve the quality of the products they have on their shelves. Ultimately, rejecting an incoming load is costly for the industry, so providing data back to suppliers about why things were rejected can improve the quality and rejection rate in the future.

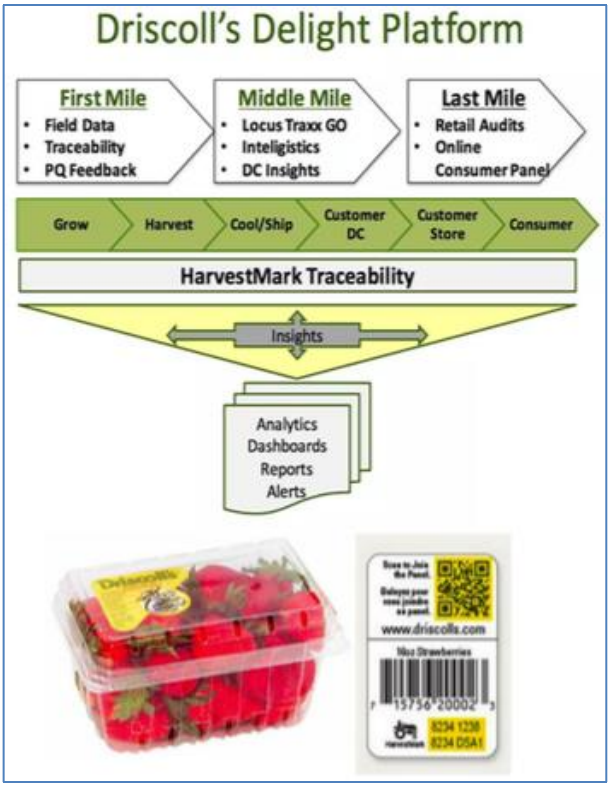


Figure 4 (Source: HarvestMark)

HarvestMark also helps brands to make data-driven decisions and ultimately improve their top lines. For example, Driscoll's berries was able to realise a 30% price premium by tracking berries and measuring characteristics such as quality and freshness throughout the supply chain using HarvestMark technology[iii]. Each clamshell container of berries has an embedded traceability code, enabling Driscoll's to aggregate and analyse data across their operations that inform business decisions at the grower, supply chain, and retail levels. The HarvestMark technology also enables Driscoll's to gain insights from consumers. Consumers are incentivized via a loyalty program to scan the code on the container and then complete an online survey. The results from this survey give Driscoll's container-level insights about characteristics like variety, location, and taste. Consumer-level insights provide Driscoll's with extremely valuable information that helps them attain significant price premiums.

Environmental and Social Impact

As described above, HarvestMark's technologies make the supply chain more efficient. Not only does this improve costs, but it also reduces waste. Food waste is a significant issue in today's food system both in terms of unnecessary costs, as well as negative environmental impacts. Currently, 10-15% shrinkage is normal for retailers; however, HarvestMark technologies help reduce this number, and, ultimately, prevent food waste before it happens.

HarvestMark also provides significant social benefits to consumers. In addition to coupons, loyalty programs, and cross-product promotions, HarvestMark enables farm-to-fork transparency. Consumers gain confidence in the safety of their food and knowledge about exactly where it comes from. For example, HarvestMark worked with Tesco after a horsemeat scandal in 2013 to apply codes to cuts of beef and track them across the supply chain. HarvestMark provided the retailer with a low-impact solution to the problems of traceability and fraud, while bringing confidence to consumers.

Implications for Australia

Though HarvestMark is already operation in the Australian market, they have found that it is a unique market with slightly different challenges and opportunities. For example, the Australian retailers tend to be "better" than U.S. retailers in terms of their inventory levels. However, Australian retailers have not yet prioritized traceability or direct reach to consumers. On the grower side, HarvestMark has found it challenging to gain traction in Australia due to the lack of regulatory requirements around traceability, such as for food safety or recalls.

In the absence of a large food safety issue and subsequent media and/or regulatory attention, HarvestMark sees their opportunity in Australia being around connecting to consumers.

Case Study: Farmers Business Network

"At Farmers Business Network, we're bringing in true competition and a global set of competitors. That's what has been lacking in farming. Farmers have been held hostage by local competition or the lack thereof. By nature, farmers are geographically dispersed and so there's only ever limited competition in their region. At a very basic level, that's what FBN does: brings true competition,and true independent information, entirely driven by growers, to help them make the best decisions. This combination is extremely powerful for our farmers. We've helped them make better decisions and ultimately saved them lots of money"

- Charles Baron, Co-Founder and VP of Product, Farmers Business Network

Executive Summary

The Farmers Business Network (FBN) is a software-as-a-service platform that enables farmers to access anonymous, aggregate analytics about all aspects of their farming operation, including agronomic data, pricing, and finance, as well as participate in a marketplace of services and products backed by a lowest price guarantee. FBN also includes the *Seed Finder* system, the world's largest real-world seed performance database, which helps farmers save time and money on their planning while optimizing their performance.

Farmers pay $500/year to join the network, and can save up to 50% on input costs (20-30% on average). As farmers add more of their data, they unlock additional insights derived from the aggregate data from over 11 million acres supplied by a network of over 3,000 farmers. All data is anonymous and insights provided back to individuals are aggregated.

FBN is headquartered in Silicon Valley California and has raised $48 million in venture capital funding. FBN currently operates in the United States, with plans to expand into Canada and Australia in the future.

Background

Company History

The Farmers Business Network (FBN) was founded in 2014 by Amol Deshpande and Charles Baron, former partner at venture capital firm, Kleiner Perkins Caufield & Byers, and former program lead for energy innovation at Google, respectively. Deshpande and Baron, along with a group of farmers who remain advisors to FBN, were focused on the idea that farmers like to network and share information, but historically have had limited ways to do so. Farmers share information through anecdotes, at the coffee shop, and sometimes in special peer groups set up to be non-competitive. However, these traditional channels lack the power of technology and data to bring insights to farmers. FBN was created to give farmers access to more data that can help them make educated decisions about what to buy and plant, and how to operate their farms from planning and financing through to harvest and marketing.

FBN has raised $48 million so far to help them achieve this goal. In April 2014 they raised $5.6 million in a funding round led by venture capital firm Kleiner Perkins Caufield & Byers, and then in June of the same year raised another $3.3 million from Google Ventures, the venture capital arm of Google. The following year, in May 2015, FBN raised another funding round of $15 million, led by Google Ventures, and then quickly added another $20 million from Acre Venture Partners, the venture capital arm of Campbell's Soup.

FBN released their flagship farm analytics service in March 2015- which included *Seed Finder, Yield Potential,* and *Farm Benchmarking*. The Seed Finder system helps farmers find the highest performing seed varieties and helps match the best varieties to each of their fields. FBN members upload their data to FBN, which is then anonymized, aggregated, and used to provide collective insights about price and performance back to individual members.

In early 2016, FBN launched *Procurement Platform*, which has since been renamed to *FBN Direct*. FBN members expressed that they lacked a trusted resource for buying inputs, and felt they lacked negotiating power with retailers and consequently were often overcharged. FBN validated this pain point with their own research, concluding that, "farmers could pay up to 300 percent difference for the same product and even 40 percent difference within an hours drive."[iv] *FBN Direct* uses technology to help support collaboration among farmers, allowing them to share their knowledge and strengthening communities. *FBN Direct* helps members save money on inputs and creates a transparent market place for services and equipment.

Figure 5: FBN Member Distribution (source: company website)

At the end of 2016, FBN launched a new product, *Crop Marketing*, to help farmers directly access contracts with buyers (e.g., food processors and manufacturers). FBN also provides their members with access to low cost finance.

Company Structure

FBN is headquartered in San Carlos (Silicon Valley), California. They also have a network of regional offices around the United States in places such as Davenport, Iowa, and Sioux Falls, South Dakota. The regional offices are staffed by a team of FBN field representatives who work directly with farmers. The field representatives handle customer on-boarding and data entry, sales, and equipment support, as well as serve as retail agents to support purchases on FBN Direct. FBN currently has around 125 employees across the U.S.

FBN members are located in over 30 states across the U.S. Figure 1 shows FBN membership in early 2016. It has since increased, and members are mostly concentrated in the corn belt and Montana's golden triangle.

Products and Services

At its core, FBN is a network of farmers who share their data and receive valuable information about how to optimize all aspects of their farming operations. FBN members upload data including input types and prices, yield maps and input performance information, invoices, market reports, varietal data, and more. FBN also integrates with equipment to capture raw farm data. As farmers upload more data, they unlock aggregate insights from all

FBN members. These data help farmers find the best products and services for their operation, at the best prices.

FBN members pay $500/year for access to the network, which includes four main products/services: Analytics, Direct, Crop Marketing, and Finance. *FBN Analytics* includes the seed finder database and price transparency features. *FBN Direct* (formerly "procurement platform" is a marketplace for services and products, such as equipment, chemicals, and independent agronomists. *FBN Crop Marketing* provides members with dynamic profitability data and the ability to contract directly with manufacturers. Finally, *FBN Finance* provides access to low cost finance from 3rd party providers.

All members, regardless of size of number of acres, pay the same price and can access the same services. However, each farmer determines what data they will access in deciding how much of their own data to upload. By uploading data, farmers unlock more insights from across the network. Big farms, therefore, tend to contribute more data, making the network better and unlocking additional services (e.g., seed or chemical invoices, or yield data).

This model ensures that farmers receive value for the data they provide. For example, if a farmer adds data for one year, he/she will get access to benchmarking, mapping, analytics for the crop, and ROI for that year. If the farmer adds historical data, he/she will access rotational analytics, trends, crop analytics over time, and multi-year average yield and trend maps.

Market Presence

The FBN network currently comprises over 3,200 farmers across over 11 million acres (4.4 million hectares) across the United States. The system is optimized for broad acre crops, but FBN has price transparency data on between 25 and 30 different crops, including corn, beans, wheat, cotton, peaches, broccoli, tomatoes, pulses, and specialty crops.

The Seed Finder database currently tracks over 10,000 varieties. FBN currently has enough data on over 2,500 seeds to anonymize and publish reports on seed performance. Seeds range across many crops, including corn, barley, wheat and many more. On average, each published seed has about 5,800 acres of data.

Beyond seeds, FBN also has published price transparency information (i.e., anonymous reports) on over 750 crop input products. In total, FBN has collected around 10,000 price records, and is currently growing the database at around 1,000 price records per week.

The FBN system integrates with over 60 types of precision agriculture equipment, including hourly data transfer with MyJohnDeere. FBN also has its own weather system, so farmers can pull up weather data for their own operation. The average FBN farmer adds multiple years of data. As a result, FBN has processed over 70 million acres of data. They currently process 1-2 million acres per week.

Future Strategy

In the future, FBN will be expanding the number of data types able to be used in their system. For example, FBN is looking at soil data and associated seed response rates, as well as additional chemical and fertilizer data, hoping to move to full yield by fertility analysis capabilities (currently they just do nitrogen). FBN is also adding support for more analytics to help farmers with more timely decsion making. They are looking at capabilities such as input selection, marketing, and yield prediction. Finally, FBN is looking to help farmers get more information about crop markets and enhance their ability to market their products.

Use Case: Farmers Helping Farmers

Identification of the Use Case

Farmers Business Network has identified a use case for using technology and the power of crowdsourcing to provide farmers with enough information to change the market dynamics for sourcing inputs.

Before FBN, many farmers felt frustrated about a lack of transparency in input pricing particularly in markets that were dominated by a relatively small number of large multinational corporations. Product choice was also often limited to more expensive branded products that had supply agreements with co-ops and agencies that farmers dealt with.

The Farmers Business Network Product Suite

FBN Analytics

There are two components to FBN Analytics: (1) agronomics and price transparency; and (2) the Seed Finder database. The former gives farmers the ability to compare the prices they pay against the market average, by location, and the FBN average. Farmers can calculate the total savings available by switching to a cheaper product, as well as use the aggregate information as negotiating power with suppliers.

Seed Finder is the world's largest real-world database of seed performance. The data are entirely provided by farmers, meaning they are independent and companies cannot pay for products to be listed or for better results. FBN converts the data, shared through precision agriculture equipment, into a seed performance profile. Farmers can localize this information to specific fields, and compare performance across soil type, location, planting rates, planting dates, soil temperature, weather, and more. Ultimately, farmers are able to reduce the time it takes to do their planning from weeks to hours. Farmers can also find new seeds that will help them increase yields and save money.

FBN Direct

FBN Direct, formerly called FBN Procurement, is a marketplace where retailers and service providers can compete for farmer's business. Services include, for example, contractors, marketing services, and independent agronomists; products include all major types of ag chemicals (herbicides, insecticides, pesticides, and some fertilizers), seeds, farm equipment, and technologies such as drones. Vendors and service providers pay FBN to list their offering, and FBN takes a cut of the transaction fee between members and vendors.

FBN Direct provides price transparency, and has a lowest price guarantee for their members. By crowdsourcing pricing information across their network, FBN allows farmers to compare the price they pay with the local and market averages, as well as with alternatives that have the same composition but may be less expensive (e.g., generic alternatives that do not have a brand premium). FBN also provides a buying agent to help farmers buy at the lowest prices, and to negotiate with vendors to bring them on.

Finally, FBN Direct features, per its name, a direct shipment model. Farmers can purchase directly from manufacturers through FBN, and FBN offers flexible shipping to FBN facilities to help farmers save on costs. FBN executed over a thousand deliveries in 2016, saving growers up to 50% (20-30% on average), and simplifying the buying experience.

FBN Finance

The FBN Finance product provides members with access to low cost financing. FBN lists third party finance providers, and growers can select the provider they want. Providers benefit because they can access the advanced farmers who are able to effectively use the FBN data and tools to increase profits.

FBN Crop Marketing

FBN's Crop Marketing product, their newest, was introduced at their annual conference in December 2016. This product helps farmers dynamically calculate their profitability. Farmers can see their prices and positions in real time. Farmers can also access buyers directly. Food companies are able to offer farmers contracts directly through FBN.

Technology and Datasets

FBN is a cloud-based software-as-a-service platform that is built on Amazon Web Services (AWS). The FBN database stores and analyses, using machine learning, data from thousands of farmers across the U.S. that have been uploaded manually or through integrations with precision agriculture equipment. The database includes information on **s**ubsoil, tillage and rotational practice, seeds, application data, harvest data, weather, pricing, and more.

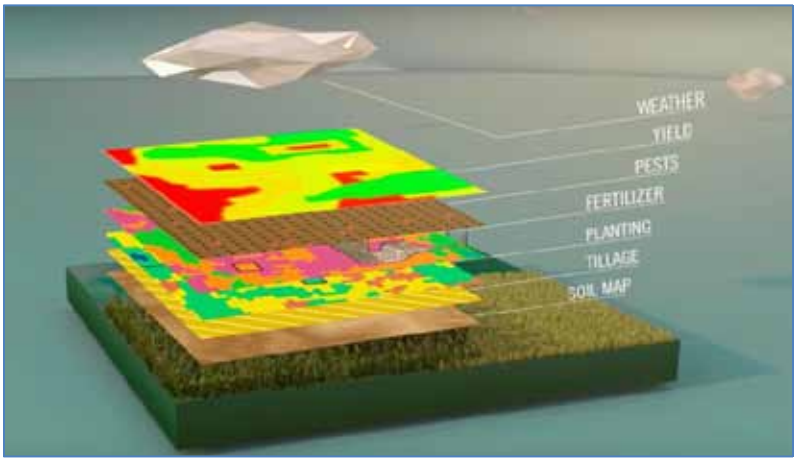


Figure 6: FBN Data Layers (source: Company Website

FBN makes the process of entering data easy. Farmers have many options for how to provide their information, including via email, Dropbox or other file sharing solutions, direct integration with equipment, manual entry through the interface, or by scanning or dropping off files of papers. FBN support staff work with farmers to teach them how to upload information, or in some cases, upload the data for them.

Once the data is uploaded, FBN cleans and processes the information. In the best cases, data are entered in raw formats so FBN can use software to automate the cleaning process and verify data quality. However, FBN always has a human review the data. The farmer is then notified and asked to do a post-calibration whereby they adjust, for example, the yield to reflect the actual yield. The data in the system is organized by field, year, and type of information (e.g., seed vs. input vs. yield) so that it is easy to interact with, and so farmers see the value of their data right away.

Challenges

FBN faces several challenges as they grow their offerings and expand their footprint across the U.S. As a start-up company disrupting the status quo, FBN has made incumbent firms nervous or even angry. This poses more than just a public relations challenge for FBN: currently the industry is generally relationship-based, and breaking into long-established relationships (e.g., between dealer/agronomist and farmer/client) may be challenging in some cases.

Farmers are often concerned about FBN's data usage and data security policies, which can be a barrier to adoption. FBN guarantees that farmers own their data, always, and that data are anonymized before use. Insights provided back to individuals are aggregated, and individuals are never identified. FBN will never sell farmer data.

As FBN moves into the retail space and directly sells ag chemicals, liability issues may pose a challenge. For example, if FBN makes suggestions about reformulations or additions to inputs, will they be responsible for outcomes? FBN is addressing this challenge by only selling in certain states where they can meet regulations, and ensuring that purchasers are licensed (and therefore liable).

Finally, FBN also faces the more general challenge of farmer fatigue. As AgTech gains mainstream attention and other start-ups attract significant capital, more solutions are entering the market. These companies are competing for farmer's attention (and dollars), and may be tiring them out, especially with solutions that do not readily demonstrate value for the farmers.

FBN's Impact

On-Farm Economic and Practice-Change Impact

FBN helps farmers improve all aspects of their operations, including the bottom line. FBN farmers yield, on average, 10% more than their peers.

FBN members realize 15-40% savings on average. Some products, like seed treatment, can be purchased on FBN for 50-60% savings. The highest savings for a single farm was $136,000, or over 50%.

These savings are realized several ways. Members can compare their practices to others in the network, ultimately getting insights about the best practices for their fields to help them optimize performance. By uploading an invoice, farmers also get benchmarked prices on inputs and services. FBN will find lower cost alternatives if they exist in the FBN marketplace (e.g., under a different brand, or even un-branded versions). Armed with benchmarked pricing data, farmers have leverage in price negotiations; the ability to negotiate input prices has saved FBN members tens of thousands of dollars. Farmers can also buy direct through FBN, rather than shopping around, and receive a "best price guarantee."

The Seed Finder database also helps farmers to improve their operations and finances. Farmers can access real-world information to help them find the best seed varieties for exactly how, where, and what they are farming. Farmers can view data such as high yielding varieties, responsiveness to rainfall and irrigation, and the impact of temperature, soil type, and crop rotations. Farmers make precise, data-driven decisions such as which varieties to buy, and where to lower populations to save money without compromising performance. Data on seed prices also helps farmers to negotiate with retailers, lowering their costs. Overall, farmers use FBN to cut days or weeks off the planning process, while optimizing their operations and improving the bottom line.

Broader Industry Impact

FBN is focused on building a connected and collaborative farming community where the farmers, rather than the retailers, have transparency and can make data-driven decisions. By bringing price transparency to the market, FBN has opened new options for purchasing, putting pressure on suppliers to compete on quality instead of relying on information asymmetries. Many incumbent firms are extremely opposed to price transparency[v], because they benefit from an opaque market. Some firms, however, recognise that transparency is what farmers want, and can grow their business by joining the FBN marketplace as a provider or suppliers. FBN therefore helps independent agronomists and smaller suppliers get customers and still benefit from the economies of scale that FBN's aggregate data provide. Ultimately, FBN is lowering the barriers to entry for new suppliers.

FBN's vast amount of data, for example for different seed varieties across different soil conditions, has implications for researchers as well. A field trial may be able to, over time, collect data for a few acres in a highly controlled environment. FBN, in contrast, can (and has) rapidly accumulate data across hundreds of thousands of acres and across various weather, soil, and operational conditions.

Environmental Impact

Currently, without FBN, farmers may over apply chemicals because of misaligned incentives in the industry. For example, in cases where agronomic advice comes from the same person who sells (for a commission) the inputs he or she is recommending, a conflict of interest arises and over application of chemicals often results. FBN's marketplace separates the sale of inputs from the agronomic advice, allowing farmers to use independent agronomists. This will likely result in an overall reduction of chemical usage.

FBN's analytical tools also allow farmers to more optimally apply their inputs, including nitrogen. Farmers can compare the impact of nitrogen across different varieties, crop rotations, and practices. Rather than focus on regulations for chemical applications, farmers can start with genetics, expand to practices, and come up with a cost-effective and potentially more environmentally friendly solution.

Implications for Australia

FBN is growing rapidly in the United States, and sees huge potential for expansion in the domestic market. FBN is also planning to expand internationally, with Australia and Canada as two likely first markets. Australia is similar to the United States in terms of technologies and agronomic practice, and is therefore an attractive market.

FBN has already gotten a lot of interest from overseas markets, including Australia, Canada, Brazil, Argentina, and more.

FBN does not see any major impediments to entering the Australian market. Like with any international expansion, there may be some data localization and availability issues, but overall FBN sees Australia as attractive.

Case Study: Agrian Inc.

Executive Summary

Agrian Inc. is a database-backed software platform that supports compliance throughout the supply chain, from an agronomist's recommendation to the farmer's actual usage, ultimately helping assure safe application of crop protection materials. Agrian presents information such as: field maps, planting records, yield maps, satellite imagery, mobile scouting, crop planning and budgeting, laboratory analysis results, nutrient management and crop protection data, and variable-rate application data. The core feature of the Agrian platform is North America's largest manufacturer product database: Agrian users can search the database by product type (e.g., fertilizer, herbicide, inoculant), manufacturer, active ingredient, registered crop or pest, and organic status, to find out detailed product and manufacturer information, as well as safety and compliance data, such as where the product is restricted.

Customers, including growers, retailers, agronomists, manufacturers and processors, and input providers, can access the Agrian platform for an annual subscription fee. Agrian helps customers optimize input usage, ensures compliance with regulatory requirements, and saves time. Agrian has also worked with several industry groups and cross-sector collaborations to promote data standards, sustainability, and efficiency in agriculture.

Agrian was founded in 2004 and is located in Fresno, California. The company currently has a strong footprint in the United States and Internationally, including in Australia. They operate across most crops.

Background

Company History

Nishan Majarian, Richard Machado and Joshua Frese founded Agrian Inc. (Agrian) in 2004. Nishan was previously the VP of Sales at Grassroots Enterprise and founder and CEO of NetFile, an electronic campaign finance reporting company. Before Agrian, Richard was the President and CEO of the Economic Development Corporation of Fresno. Joshua Frese brought the technical experience as a skilled computer engineer. When they started Agrian, their vision was to provide a series of internet-based liability mitigation, risk management, recordkeeping, and reporting applications to field level users in agriculture, coupled with product offerings that also address the needs of food processors and retailers. Specifically, they set out to help agronomists and growers safely recommend and apply materials.

The first Agrian product was based on helping growers comply with regulations in California around mandatory product use reporting for pesticide, water and fertilizer. Agrian enables growers to easily report on the various inputs and activities required for regulatory compliance, such as pesticide usage. It was clear to the Agrian team early on that they would need to work with an advisory network- namely, agronomists- as they are the ones working with growers to provide recommendations about input selection and usage. They therefore built compliance into the recommendation writing process, enabling agronomists to confidently make recommendations, and enabling growers to easily report on their practices.

The Agrian team soon realized that, in addition to advisors and growers, downstream players such as food processors and manufacturers were also interested in the same data. They decided to build a database-backed platform solution that would support compliance throughout the workflow from the agronomist's recommendation with a label verification , to the grower's actual usage, helping assure the safety of the application of crop protection materials.

The team also recognized the opportunity to take advantage of the growing trend toward precision agriculture. Agrian already had a strong foundation in data with their existing compliance database, so the choice was a natural fit to integrate with precision agriculture data. The team re-wrote their software to be consistent with precision agriculture data, and now the Agrian platform supports the full end-to-end workflow from ag retailers to growers and agronomists, and ultimately to large food companies. A platform approach has helped Agrian customers, as they can manage their whole workflow in a single environment, rather than having to deal with multiple products that support different aspects of their tasks.

Agrian has expanded across the United States and internationally, remaining based around the need to help the supply chain be more efficient and profitable, comply with government and downstream regulations, and employ more sustainable farming practices.

Present Company Structure

Agrian is headquartered in Fresno, CA. Agrian's co-founders, Nishan Majarian, Richard Machado and Joshua Frese, remain involved in the business as CEO, President, and Principal Software Architect.

Agrian has over 100 employees that work across several functional roles as follows: 40% in software development, 30% in regulatory, 20% in client support, and 10% in sales and administration. Agrian can focus heavily on development due to their targeted approach to marketing: rather than advertise in many publications, they do significant research on potential clients, and then develop targeted outreach campaigns.

In 2014, Agrian acquired Altamont Computers, Inc. The purchase was largely based on Altamont's LandView app, an interactive map view that allows users to track their workflows and provides real-time updates through aerial imagery. The LandView app was integrated into the Agrian platform.

Products and Services

Agrian provides a cloud-based agricultural data management platform to help growers, crop advisors (i.e., agronomists), ag retailers and food companies produce both safely and profitably. Agrian licenses their software to customers for an annual subscription fee. There are multiple tiers of features, but no acre fees. The platform, which works on desktop and mobile applications, includes information such as: field maps, planting records, yield maps, satellite imagery, mobile scouting, crop planning and budgeting, laboratory analysis results, nutrient management and crop protection data, and variable-rate application data.

The Agrian platform provides satellite imagery, which captures "up to two-million square miles daily, and provides access to high-resolution, multispectral, in-season imagery for timely extraction of data that directly impacts crop production and performance." Users can also interact with the map to document field-specific activities, such as seeding rates, crop performance, and input usage.

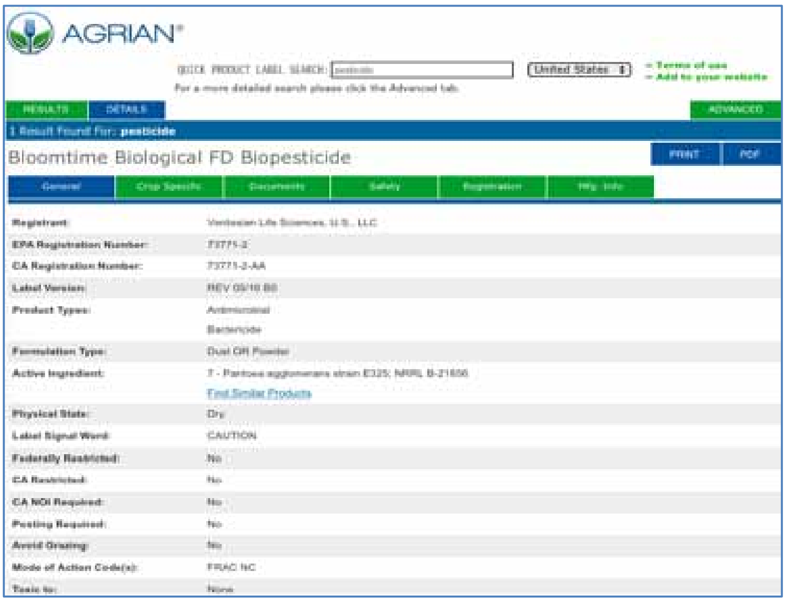


Figure 7: Example of Agrian Database Search Results

Agrian also integrates with third-party equipment, such as farm machinery, allowing wireless data transfer. The Agrian user interface features customizable dashboards, with real-time and summary report views of product usage and on-farm activities.

A core tenant of the Agrian platform is that it is backed by North America's largest manufacturer product database[1]. Users can search the database by product type (e.g., fertilizer, herbicide, inoculant), manufacturer, active ingredient, registered crop or pest, and organic status, to find out detailed product and manufacturer information, as well as safety and compliance data, such as where the product is restricted.

This database allows agronomists using the Agrian platform to back their farm management recommendations with specific product data. Further, the Agrian platform tracks all recommendations, making it simple for growers to conduct internal reviews, or to provide food safety or input/application compliance information. For example, users can manage both food safety compliance documents, as well as fill-out and send compliance documentation to government regulators or other stakeholders as required.

Market Presence

Agrian operates around the globe and across the spectrum of agricultural commodities. As they say, they support crops from "alfalfa to zucchinis." Agrian's main clients are national agricultural retailers and food companies. As these clients and their teams of advisors who use the Agrian product, operate across geographies and commodities, so too must Agrian.

[1] The database is accessible for free on the Agrian website here.

Figure 2: Footprint of Agrian Operations (Source: Company Website)

Agrian is well established in the U.S. and Canada, and also operates in Mexico, Australia, Brazil, Argentina, Chile, and Uruguay.

In addition to agronomists employed by ag retailers, Agrian also works with retail locations, as well as stand-alone advisors. In some cases Agrian works directly with growers; however, their main clients are the trusted advisors, who then bring the platform to the growers. Figure 2 shows a summary of the Agrian footprint.

Future Strategy

Agrian attributes their success in large part to their ability to attract and retain great talent. In the future, Agrian will continue to prioritize hiring and keeping good people. This is especially important in the agriculture industry, according to Agrian, as it remains a relationship-based industry where people work with people and personal connections matter.

The future for Agrian will also include expanding their integrations and establishing more partnerships to broaden the capabilities they can offer their customers. Integrations and partnerships will help Agrian to ensure they remain a platform solution that can leverage other provider's solutions and market expertise. Agrian already integrates with other data sources, such as through their weather component. Here, they work with a third-party that provides APIs. The Agrian system ingests that data in the back-end, and presents users with the information through the existing Agrian user interface. More such integrations are likely to exist in the future.

Use Case

Identification of Use Case

The Agrian team initially saw an opportunity to support growers and agronomists comply with regulations around input usage and reporting. This use case was particularly relevant for produce growers who must comply with regulations and standards from downstream customers, such as food processors, as well as governmental agencies. Agrian capitalized on the opportunity to help this industry more efficiently and cost-effectively manage their compliance data and reporting.

Macro-level industry trends are responsible for Agrian's growth and expansion beyond on-farm compliance in the produce industry. The first is the broadening of the compliance use case to commodity crops, as explained in this excerpt from a 2015 press release[vi]:

> *"To date, commodity crop growers who have adopted data management and precision agronomy tools have done so to drive efficiency and optimize production. With few*

exceptions, their adoption has been optional…Analysts foresee the potential for more demands being made on commodity crop growers for documentation of nutrients, chemicals and other applications. Increased pressure from consumers, voters, government, export markets and food retailers is being placed on the entire agrifood supply chain."

By providing detailed and accurate information about specific products, and incorporating this information into advisor's recommendation workflows, Agrian is able to help growers more efficiently use fertilisers and other inputs, mitigating the risk of negative environmental outcomes. This benefit has helped Agrian to capitalize on the trend toward environmentally sustainable farming practices. Consumer demand, in particular, has shifted toward organics and products that embody values of environmental stewardship. Food processors and manufacturers have therefore been demanding additional information and reporting about input usage. These changes have created an opportunity for Agrian.

Finally, advances in technology and a trend toward data-driven agricultural practices, and precision agriculture in general, have led to the generation of significant amounts of data from various sources. Agrian saw this as an opportunity to provide a platform solution so that all aspects of precision agriculture can be managed on one platform, rather than through multiple point solution offerings.

Products, Users, and Benefits

Agrian is a GIS-based platform that tracks and manages crop data through every stage of the crop production supply chain, from planting, to growth, and through harvest. The platform is backed by a manufacturer-indemnified database (i.e., a database of information based on the labels of agricultural products). Users can also input data, or pull in data from third party systems such as imagery providers or farm machinery.

The Agrian system tracks activities and recommendations, including but not limited to permitting, field mapping and scouting, trap counting, crop protection and nutrient application, and pre-harvest interval (PHI) dates[2].

Retail agronomists are a key user and demonstrate an important use case. Agrian helps agronomists make recommendations to growers on a variety of topics, including fertiliser applications, seed usage, pesticides and crop protection, fertility, and other types of simple and more involved prescriptions. More specifically, Agrian supports:

- Field scouting, including a system to manage soil and tissue data, and lab integrations to receive and store testing results.
- Crop planning and budgeting through to crop records.
- Zoning of data, including yield, imagery and planting data.
- Imagery integrations, including third-party integrations, such as drones or satellite imagery.

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[2] PHI: the minimum amount of time, usually measured in days, that must occur between the final application of a pesticide and when a crop is harvested

- Variable rate and nutrient management plans through a fertility recommendation system.
- Analytics.

Agrian is a tool for crop consultants and other trusted advisors. The platform supports these professionals, digitizing and streamlining their work. For example, consider an agronomist making an herbicide recommendation to a grower. The agronomist can look up the herbicide in the database and view properties such as: label commodities, label rate of application, amount of applications allowed for the year or cropping season, and whether the product is allowed for that specific crop. The agronomist can then write a recommendation, which is stored in the system, the recommendation can be electronically shared to the grower, too. This workflow protects the agronomist from writing a recommendation for a commodity that it is not registered for: the system will not let the agronomist, for example, exceed the maximum rate of application that is indicated in the database.

Agrian provides several benefits to its customers, which include growers, retailers, agronomists, manufacturers and processors, and input providers. First and foremost, Agrian helps customers comply with regulatory requirements from downstream customers and government. By managing data across the entire workflow digitally, Agrian ensures consistency and accuracy, and saves time.

Agrian can also generate and share reports through a secure network. For example, Agrian can help securely share information from agronomist, to grower and farm manager, to retailer at harvest or to food processor. Agrian also sends data to state and federal agencies as needed. All data sent only with explicit permission from users.

Agrian also helps customers to understand and improve their practices. By allowing users to access historical data, they can make modifications to be more efficient, productive, and sustainable. Having all of this data in a digital format saves users time and reduces the chance of error, both in sharing information and in writing recommendations.

Finally, Agrian’s database-backed approach, and support for the end-to-end workflow, helps food companies to ensure their products are legally compliant. This in turn reduces their liability and ensures food safety for consumers.

Agrian has free and paid versions of its products for each user type, including:

- Agrian Advisor (free) and Documented Advisor (paid)
- Agrian Grower (free) and Documented Grower (paid)
- Agrian Applicator (free) and Documented Applicator (paid)
- Agrian Handler (free) and Compliance Handler (paid)

The paid version of the Agrian software, Agrian Documented, has additional features that allow users to[vii]:

- Manage food safety compliance documents, automatically
- Fax documents and work orders directly
- Export your data to an Excel spreadsheet

- Archive, upload, and transmit compliance documents
- Use the Agrian Documented logo in your marketing materials

The label database is free to use and access via the Agrian website.

Finally, Agrian also provides an opportunity for manufacturers to advertise through their platform. Manufacturers can promote their products, for example with banner ads, to a highly targeted audience of agronomists and growers.

Partnerships and Collaborations

Agrian has a number of ongoing partnership and collaboration efforts. For example, the Agrian platform integrates with equipment manufacturers, processing data from controllers such as John Deere, FieldView, and Slingshot. These integrations allow wireless data transfer and telemetry options between the machines and the Agrian platform.

Integrations with equipment providers enable Agrian to support users and consistently manage data along the round trip workflow, from documentation in Agrian, to accounting, to data collected by equipment, and back. The benefits for users of this seamless data flow and shared database approach are better data accuracy and consistency across the workflow.

Agrian also has ongoing collaborations with Crop Production Services in the USA and Canada, as well as through their South American network in countries such as Brazil, Argentina, Chile, and Uruguay.

Agrian has also been involved in collaborative efforts to design and implement fertiliser benchmarking programs, such as the Canadian Field Print Calculator and the Field to Market Initiative in the US, and data collection standards, such as The Open Modus Standard. These initiatives are discussed in detail below.

F2M and CFPI Initiatives

The Field to Market (F2M) and Canadian Field Print Calculator (CFPI) initiatives are not-for-profit, collaborative efforts to provide research and tools that help participants along the agri-supply chain to adopt more transparent and sustainable practices. These efforts have largely been spearheaded by food companies, such as General Mills, but also include participants across the food system, such as agribusinesses, retailers, and public sector partners (e.g., universities).

These initiatives are focused on the development of market-driven science to measure agronomist performance and improve sustainability performance along the supply chain. They seek to define metrics and data standards for sustainability (e.g., carbon sequestration, tillage, land use efficiency, etc.).

The CFPI is also looking to build a database calculator to advance the use of precision agriculture and geospatial data for agriculture. However, the current systems require lots of manual inputs, meaning that adoption is low. For example, growers must manually input data per field, acre, or year. Further, there exist many partial and point solutions to store and analyse the data, so the formats and fields are not standardized. It is therefore hard to make use of such a calculator.

The CFPI is working to build an integrated solution that improves decision making for the farmer and agronomist. The CFPI is now looking at building an API that would leverage power of the systems, like Agrian, that collect, store, and analyse this data, to plug directly into the calculator, removing the need for manual data entry.

This would save time for all parties involved, as well as increase adoption of the metrics and approach that drive the CFPI.

Agrian is involved with both organizations, sitting on the committees and working with the technical committees to develop APIs and standards for securely sharing data.

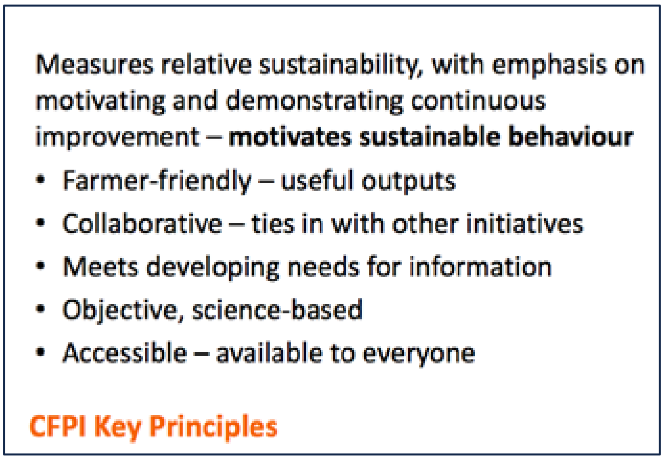

Figure 8: CFPI Key Principles (Source: 2014 Presentation to Canadian Roundtable for Sustainable Crops[viii])

Broader Impacts

Economic Impact

On-Farm Impact

Agrian's ultimate objectives, are to help their customers grow safely and profitably, which they believe are two major pillars towards growing sustainably. Their compliance engines help clients to grow while ensuring safety and compliance while the precision agronomy components drive profitability.

Agrian has two main economic benefits for growers. First, Agrian helps growers to be more efficient in their use of inputs, such as fertilisers, pesticides, and seed populations. More efficiently using these resources can help to both decrease costs, as well as increase yields, (e.g., by applying products in optimal quantities based off the soils and or crops responsiveness) thereby increasing profits.

Second, Agrian helps growers to ensure they are in compliance with regulatory bodies as well as with downstream customers, such as processors and manufacturers. Non-compliance can cost growers huge sums of money, for example through the recalls, lawsuits, or just product losses. Avoiding these potential costs and reducing liability can be a huge economic benefit for growers.

Broader Impacts

Beyond the farmgate, Agrian helps the entire supply chain to be more efficient with resources. The platform saves agronomists time (and therefore money) by digitizing and providing end-to-end support for recommendation writing, field mapping, label-verification, and disseminating information to clients. Agrian's comprehensive database and ability to check for compliance electronically also ensures accuracy and reduces risk, minimizing costly mistakes.

Agrian also provides a secure way to share crop data across processors and government agencies, saving time and ensuring accuracy.

And further, Agrian's platform approach to data management, and support of industry interoperability standards like AgGateway's ADAPT and ISO, Agrian also makes it easy to integrate and enables simple third-party integrations, saving time and money, allowing for flexibility as new technology providers emerge.

Finally, specifically for processors, Agrian helps to streamline management of their grower customers (which can sometimes total hundreds of growers) and service providers by providing a single system for everyone to use. Rather than have to share information across systems, or manually manage data in spreadsheets, Agrian saves time by consolidating information in one place.

Social Impact

Sustainability is one of the five pillars on which Agrian was founded, and as consumer demand for environmental stewardship increases, Agrian continues to promote environmentally conscientious agricultural practices. Agrian also allows clients to document their practices and build up a data history that can be used to share information externally, or conduct internal reviews to improve practices. Currently, Agrian is working to help the Great Lakes Region of the U.S. with nutrient management planning. Agrian is also a member of the 4R Nutrient Stewardship Initiative[3].

Agrian's ability to help the supply chain effectively manage and monitor input usage also reduces food safety risks. This is ultimately a huge benefit to the end consumer.

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3 http://www.nutrientstewardship.org

Industry Impact

Beyond the economic and social impacts of the Agrian platform, the company has been involved with collaborative efforts to improve agricultural data management.

In 2015, Agrian helped to develop the The Open Modus Standard alongside groups in the U.S. and Canada. At the time, there were hundreds of methodologies being used to collect and analyse soil data, including a huge variation in terminology used, minimum acceptable criteria for certain conditions, and different extraction methods and sample depths. They needed a standard that would guide how agronomic labs collect, measure, and report on soil analysis data to advisors.

Because simultaneously precision agriculture was gaining traction, there were broader implications for the Modus standard. Many different organizations were developing and using data-driven solutions; however, due to a lack of data exchange standards, the systems could not effectively work together. Soil analysis was just one example where it was nearly impossible to reliably get data and analyses out of labs and into the various farm data management systems being used to implement the decisions that the analyses suggested. With Agrian's help, The Open Modus Standard was developed, providing labs with standard terminology and minimum criteria, denoting extraction methods, and setting a human and machine-readable XML format for data entry and storage.

> Agrian believes successful ag data solutions should be modular, enterprise friendly and built for every link in the agricultural food chain. That's why we've been a leader in the development of an industry standard for agronomic labs to use when collecting, measuring, and reporting field sample data and analytics: the Open Modus Standard, which provides the industry with constancy in fundamental direction for data management and exchange that can be used across farm management information systems. Agrian also supports industry interoperability standards like AgGateway's ADAPT and ISO and is an active participant in driving understanding of The Fertilizer Institute's 4R Nutrient Stewardship initiative.

Figure 9: Agrian's View on Data Standards (Source: Company Website)

Implications for Australia

Agrian on-boarded their first Australian client on 15 November 2016. Expanding to Australia has been relatively seamless given their strong presence in Canada and the USA, and the similarities between language and cropping systems, according to Chad Matthies, VP of International Business Development for Agrian. The Australian agriculture industry is a good fit given the characteristics: large grain farms, dry land, crops such as cotton, wheat, and canola, plus Australia's vast horticultural sector fit the Agrian value proposition well. Agrian is also looking to help their clients make the most of their data, capitalizing on the growing trend toward the adoption of new technologies and upgrading equipment.

Though there has been significant demand in Australia for a product like Agrian, and Mr. Matthies is confident about Agrian's potential, there are also barriers for entering Australia. For example, the time difference between Australia and North America. Agrian intends to have boots on the ground, or local personnel. This local presence will help with the knowledge of the Australian market, industry, and potential customer base.

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[i] http://www.producetraceability.org

[ii] http://investor.trimble.com/releasedetail.cfm?releaseid=907841

[iii] http://www.santacruztechbeat.com/2016/06/23/driscolls-delivering-delight-technology-enabled-supply-chain/

[iv] https://agfundernews.com/farmers-business-network-raises-20m-series-b-2.html

[v] http://www.croplife.com/editorial/paul-schrimpf/crop-input-selling-return-of-the-price-list/

[vi] http://www.precisionag.com/technology/computers/agrian-releases-updated-ag-data-management-platform/

[vii] http://www.onfarm.com/agrian/

[viii] http://www.canadagrainscouncil.ca/uploads/Weber_-_Field_Print_Calculator_Nov_26.pdf

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