A CHANGE MANAGEMENT APPROACH TO UNLOCKING THE VALUE OF DIGITAL AGRICULTURE FOR FAMILY FARMING BUSINESSES

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Abstract

Digital is the next wave of innovation for agriculture, enabling data flows and data-driven actions along the agri-food value chain. Yet family farming businesses are struggling to comprehend the value of changing to digital methods of data collection and use. Working with all internal and nominated external members of a farming business team, this research employed a mixed methods research approach to establish *How can an adoption framework improve uptake and use of digital agriculture by a family farming business?*

Whole-of-team engagement and clear communication is crucial for successful change. By combining change management and diffusion of innovation theories with maturity modelling a conceptual novel adoption framework was proposed consisting of two evaluation tools and a Change Guide. Using surveys, video tutorials and industry resources the evaluation tools were populated with task and situation statements which were tested, reviewed and agreed by the participants using a Delphi method. These tools quantified the current state of digital capability or digital processes, and highlighted strengths and weaknesses by skill, characteristics and focus activities. These findings flowed into the third part of the framework; the Change Guide which is used to address a digital change specifically desired by the business.

Using the team approach highlighted inconsistencies in individuals' perceptions and priorities for digital change. Before using the framework, the participants struggled to present their current digital state of capability or process. Using a formalised approach to change was unfamiliar to the teams but this bottom-up approach was accepted by the participants. To achieve wider uptake of the framework, targeted extension would be required.

An embedded study with providers of digital solutions for agriculture

investigated their perspectives on, and approaches to, adoption. Providers also struggled to present the value proposition of digital change. An ecosystem for influencing human, technological and data factors was described.

The ongoing failure to unlock the value proposition of digital agriculture is considered to be due to digital solutions being offered at a task, rather than a process level, and failure to align digital solutions with human influences on adoption. The adoption ecosystem for providers and adoption framework for users offer a way to overcome these limitations and illuminate the value of digital change and the pathway to adoption.

Certification of Dissertation

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

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special people you are in your own right. Together you have made tackling this challenge so much more rewarding and in the immortal words of Winnie the Pooh, ‘When you see someone putting on his Big Boots, you can be pretty sure that an Adventure is going to happen’.

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List of Abbreviations

4G or 5G	Fourth or fifth generation
ASRIS	Australian Soil Resource Information System
App	Application
BOM	Bureau of Meteorology
CMM	Capability maturity model
CRC	Cooperative Research Centre
DA	Digital agriculture
DKSA	Digital Knowhow Self-assessment tool
DPM	Farming Businesses Digital Process Maturity tool
DSS	Decision support system
DST	Decision support tool
EU	European Union
FAIR	Findable, accessible, interoperable, reusable
FAO	Food and Agriculture Organisation
FAQ	Frequently asked question
FDI	Fire danger index
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ha	Hectare
ICT	Information and communication technology
IoT	Internet of Things
MLA	Meat and Livestock Australia.
NBN	National broadband network
NDVI	Normalised Difference Vegetation Index
OH&S	Occupational health and safety
PA	Precision agriculture
PAR	Participatory action research
RQM	Main research question
SDG	Sustainable Development Goal
TAM	Technology acceptance model
UK	United Kingdom
UN	United Nations

UNE	University of New England
USA	United States of America
VRT	Variable rate technology

Chapter 1: Introduction

When a new technology for farmers meets a need, is reliable, easy to use and ‘cost’ effective they will adopt; otherwise, we would still be in the Stone Age. However, these adoption criteria are perceived at a personal level and are influenced by an individual’s networks and innovativeness. This is especially true of the purchasing decisions in a family farming business—the dominant business structure in Australian agriculture (Kaine et al., 2011; National Farmers Federation, 2017). At the outset of this research, it appeared that the socio-cultural and socio-psychological aspects of digital adoption in agriculture were being overshadowed by a focus on the advantages and disadvantages of the technology. It was not uncommon to hear digital agriculture (DA) innovations described as ‘a solution looking for a problem’.

Placing digital technology as the focus of adoption not only disregards its societal influences; it also distorts users’ understanding of the value of digital change. Digital is about the use of digitised data, not about the technology itself. To gather, integrate, analyse and act on these data often requires adoption of packages of interconnected technologies working with interoperable, digitised datasets; in other words, digitalised systems. In the waves of agricultural innovation, DA is considered the fourth wave, following precision agriculture (PA). In this research, PA is viewed as a subset of DA, with the former embedded in DA but specifically relating to use of technology to manage variability and improve resource use efficiency on farm (International Society of Precision Agriculture, International Society of Precision Agriculture, 2019). By comparison, DA is regarded in relation to the use of digital data, digitalised processes and digitally transformed systems that are facilitated by data flows up and down the value chain, involving all aspects of the food and agricultural industries.

On-farm adoption of approaches based on digital data can be complex. Prior to commencement of this research, a suite of Australian research projects identified six key barriers to adoption of DA (Barry et al., 2017; Lamb, 2017; Perrett et al., 2017; Skinner et al., 2017; Wiseman & Sanderson, 2017; Zhang et al., 2017). These included limitations of digital literacy, insufficient telecommunications connectivity, lack of available data and inability to articulate clear value propositions for change. This researcher was privileged to produce the summary report from these six projects (Leonard et al., 2017), the outcomes of which influenced subsequent considerations regarding this thesis on 'A Change Management Approach to Unlocking the Value of Digital Agriculture for Family Farming Businesses'.

With over 30 years of experience in translating complex technical information into practical solutions for agriculture, this researcher has seen many technologies successfully adopted by farmers across the globe. The researcher's experience of primary production suggests that successful adoption takes time, support and the mindset to change. In addition, she is very aware that the more complex the change and the less obvious the benefit of the change, the harder it is to dedicate the time and resources required to implement the change. Being embedded in a family farming business in rural Australia, the author has first-hand experience of these businesses' methods of operation and approaches to business decisions. That is, they act like non-specialist rather than organisational purchasers, with decisions influenced by personal preferences (Kaine et al., 2011). She is also familiar with members of family farming businesses having to be multi-skilled, not specialists, and often lacking the time, confidence and support to increase their digital literacy. Therefore, to unlock the value of DA for a family farming business the aim of this research was to deliver practical solutions to meet their specific management style and support them on their DA adoption journey.

1.1 Aims of this Research

Adoption barriers are multifaceted, interrelated and influenced by the perceptions of the adopter, aspirations of the business and attributes of the technology. Unlocking the value of DA could be approached from multiple directions. However, at the beginning of this research in 2018, two clear gaps emerged from the literature review that aligned with the researcher's areas of specific interest. These were:

- lack of appropriate guiding frameworks designed for on-farm DA adoption
- minimal understanding of commercial providers' points of view on the barriers to DA adoption.

To address these gaps in the literature, this research aimed to understand the DA technologies, digital data and digitised processes currently used by family farming businesses. With this information, as well as an improved understanding of why and how digital change is currently initiated, this researcher wanted to work with family farming businesses to develop and test an adoption framework. The framework design aimed to identify strengths and weakness in digital capability and process that could be aligned with a desired digital change.

However, during the literature review process, it became clear there had been little research on the barriers to digital adoption from the perspective of providers of digital products and services. Without the appropriate technology, data sources and connectivity, digital adoption is less likely to occur and changes less likely to be permanent. Consequently, this embedded study involving commercial providers of digital goods and services investigated their perception and approaches to adoption barriers.

It was hoped that improving family farming businesses' ability to articulate their specific DA value propositions would bridge the divide between providers and potential users of DA. It was envisaged that with this shared knowledge, more appropriate digital goods and services could be developed and identified for adoption by a family farming business.

1.1.1 The Family Farming Business

The goal of this research was to place people rather than technology at the focus of the adoption. Family businesses are identified with a range of characteristics, all of which are also reported for farming businesses (Fulton & Vanclay, 2011; Hubler, 2009). In addition to acting like a consumer/non-specialist purchaser rather than a corporate purchaser, family businesses are known to use tacit rather than explicit knowledge and have poor internal communication (Pitts et al., 2009; Poza et al., 1998). Family farming businesses tend to have flat management structures with a few people executing a diverse range of tasks, with varying levels of responsibility (Pannell & Vanclay, 2011). Consequently, team members are often generalists rather than specialists and may have limited computer-based or digital training. For these reasons, the family farming business was selected as the target for this research to help address limitations and capitalise on opportunities offered by these business structures in relation to DA adoption.

A novel approach to data collection was taken by working with multiple members of family farming businesses, including trusted advisers. In this way, the whole team was engaged in identifying their businesses' unique digital value propositions and providing approaches to overcome the barriers relevant to each family farming business.

1.1.2 Commercial Providers

Australian agriculture is viewed as an innovator in PA (Lowenberg-DeBoer & Erickson, 2019) and an early adopter of technology, with a high proportion of the agricultural and rural population having access to computers, smartphones and broadband connectivity (Trendov et al., 2019). The commercial providers of digital goods and services are often involved in PA and, more recently, DA. This is necessary and desirable because DA is immature, yet fast moving. This study sought to work with experienced providers who had breadth and depth of experience in provision, rather than those providing disruptive DA technologies considered under the auspices of agtech (see below).

1.2 Definition of Terms

Every industry has its own vocabulary. The following definitions are based on the usage of these terms in agriculture or the wider digital industry:

- Agtech: businesses developing digital solutions (also called developers) for agriculture, generally being new providers in the agricultural market
- Broadacre: in Australia this refers to large scale crop production, usually grain crops but can include irrigated crops such as cotton
- Digitised: conversion of data from an analogue, handwritten format to digital collection and storage of data
- Digitalised: processes executed using minimal operator intervention and information-intensive technology, connectivity solutions and interoperable datasets
- Digitally transformed: automated processes using robotics and artificial intelligence to deliver new approaches to management, production and marketing along the agri-food value chain
- Family farming business: farm business owned and operated by members of the same family, regardless of whether the business is registered as a company, partnership or sole trading structure

- Mixed farming: a farming business that has multiple income streams usually from growing broadacre grain crops and pasture for livestock grazing in rotations across the same areas
- Process: a combination of individual tasks, that are supported by data and required to be performed concurrently or simultaneously to achieve a predetermined outcome
- Provider: commercial business delivering hardware, software and digital services or combinations of these to agriculture.

1.3 Overview of Thesis Structure

This mixed methods research is presented in the traditional thesis structure as follows:

- Chapter 1: Introduction and background to the research
- Chapter 2: Literature review—identifying of gaps in the literature and rationale for undertaking the research
- Chapter 3: Methods—encapsulating a review of research methods and explanation of the foundation of a mixed methods approach
- Chapter 4: Methodology offering an introduction to the three-part adoption framework, plus an in-depth description of the selection of sample population and data collection instruments for the research, including the embedded study with commercial providers; also detailed is the construction of the evaluation tools—two parts of the adoption framework
- Chapter 5: Results and analysis based on surveys and exit interviews
- Chapter 6: Results and analysis of semi-structured interviews with commercial providers of DA products and services

- Chapter 7: Results and analysis of the responses to the video tutorials that presented information and posed questions to team members
- Chapter 8: Results and analysis of evaluation tools as means to quantify the current state of digital knowhow and digital processes
- Chapter 9: Discussion including the presentation of the DA adoption ecosystem checklist and three-part adoption framework, together with limitations of this research and future opportunities
- Chapter 10: Conclusions
- Appendices are labelled alphabetically in chronological order as mentioned throughout this thesis.

The following chapter provides a deep dive into the literature relating to DA and on-farm technology adoption, and approaches that could promote successful digital change in family farming businesses. It concludes with identifying the research questions addressed by this thesis.

Chapter 2: Literature Review

2.1 Overview

This chapter provides a literature review of relevance to on-farm uptake of technology, especially digital technology, and if and how uptake can be improved. As a relatively immature industry sector, the term *digital agriculture* lacks a clear, concise and consistent definition. Individually, the terms *digital* and *agriculture* each represent a diversity of systems. In combination they offer a new suite of tools, processes and systems that rely on connectivity, from which interoperable datasets are starting to emerge.

For industries and businesses in the agricultural value chain to embrace digitalisation and deal with digital disruption, there must be a clear value proposition, yet value is a very subjective term and family farming businesses tend to be highly individualistic. Studies identifying factors that contribute to promoting and preventing the development of value propositions and that support on-farm adoption of technology are presented. Because of the immaturity of DA, it is necessary to examine adoption patterns of previous technologies, with PA offering the closest parallel. Literature that clarifies the specific challenges relating to on-farm adoption of DA is presented.

Finally, this literature review assesses potential solutions to help support the on-farm adoption of DA. How farmers learn about and address technology adoption in Australia is investigated. With family farming businesses dominating agricultural production in Australia—indeed across the globe—the literature outlining adoption issues specific to the operation of these business structures has been sourced.

Drawing these threads together, the final part of this chapter presents the case for this research to be undertaken and suggests how it might help family farming businesses address the challenge of *going digital*.

2.1.1 Defining Digital

The use of information and communication technology (ICT) and digital systems is not unique to agriculture. Indeed, it is estimated that over half the world's population has a mobile phone for communication, currently the most widely adopted digital system (Taylor & Silver, 2019). ICT and digital systems have the same foundation, hardware and software; digitalisation extends and enhances these elements through the additional components of connectivity and data access (Evans et al., 2017). An example of this evolution is from the mobile phone to the smartphone. The mobile phone facilitated calls without a wired connection; the smartphone transmits voice and data through fourth and fifth generation (4G and 5G) connectivity solutions. Digital systems are disrupting traditional approaches to work and leisure, via paperless workflows, wearable technology and autonomous vehicles, to name but a few innovations (Manyika et al., 2015).

Because of the relatively invisible nature of databases, algorithms and even connectivity solutions, much of the discussion about digital disruption revolves around the more easily observed technology; that is, hardware. Consequently, the required datasets, analytical systems and connectivity can be overlooked. As Savic (2019) explained, digital change consists of three parts—digitisation of data; digitalisation of processes; and digital transformation—creating new, disruptive systems (Figure 2.1).

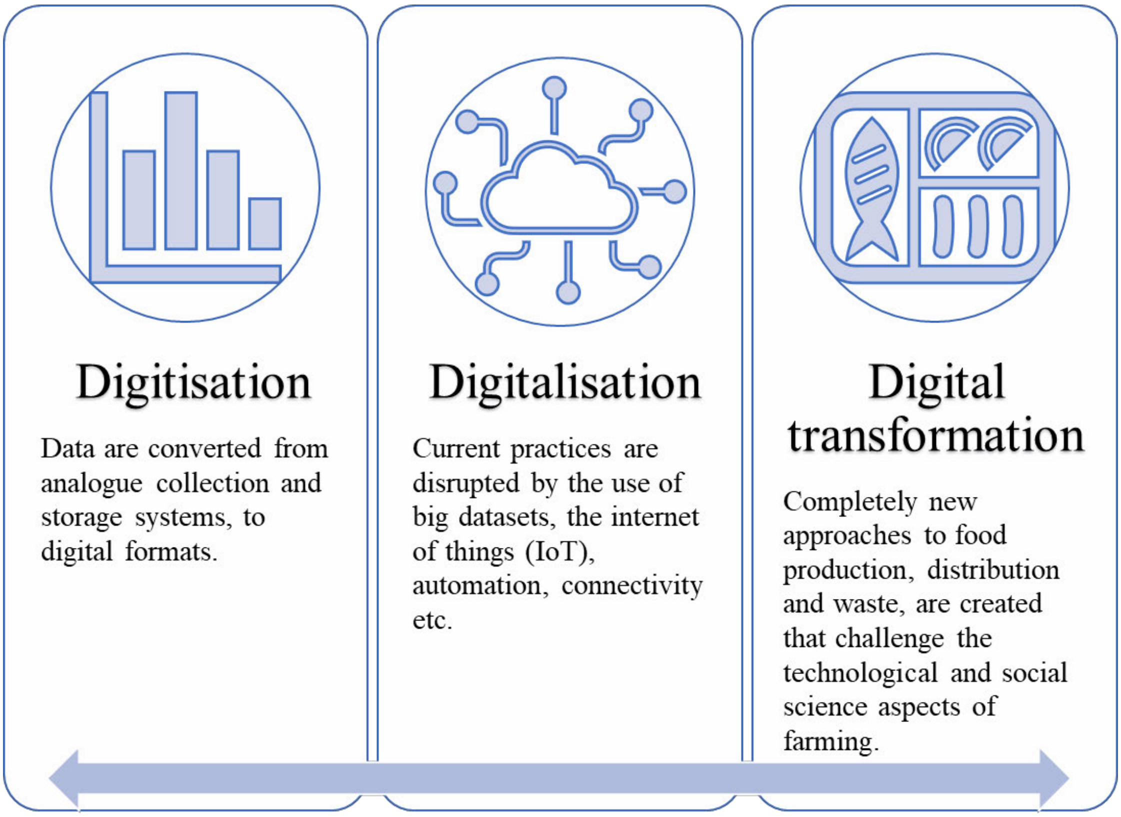


Figure 2.1

The Three Elements of Digital Evolution (Savic, 2019) Applied to Agriculture

The term *digital* is widely used in our modern vocabulary, with several meanings. In this thesis, the term d*igital* refers to systems that record or transmit information in the form of binary digits (Bits), and *technology* describes methods, systems and devices that are a result of scientific knowledge being used for practical purposes (COBUILD Advanced English Dictionary, 2021, Definition 1).

The addition of the words ‘agriculture’, ‘manufacturing’ or ‘architecture’, for example, to the word ‘digital’, specifies the industry sector for which the digital technologies have been developed. The hardware and software may be similar, or even common across industry sectors—a factor that is attracting non-traditional suppliers of technology to agriculture (Relf-Eckstein et al., 2019)—however, the datasets that underpin digitalisation of agriculture are generally highly specific and often specialised to a field; farming business; region; value chain segment; or industry (Barry et al., 2017). Despite this specificity, datasets for digitalised processes need to be interoperable. To achieve this, common data standards and languages are required (Bahlo et al., 2019).

2.1.2 Defining Agriculture

The term *agriculture* embraces a diverse range of production types, scales, intensities, business structures and abilities (Fulton & Vanclay, 2011; Kilpatrick, 2000; Wilson et al., 2009). These variables can be combined in multiple ways, with location, environment, markets, and the goals and values of those running the business influencing the combination selected (Pannell & Vanclay, 2011). In addition, many of these variables are in a state of flux, often changing because of factors beyond the control of the farming business; for example, daily changes in weather and long term changes in climate or international exchange rates and commodity prices. Managing these dynamic situations requires farming businesses to have access to a range of skills and an appetite for risk, and to regularly reassess decisions (Kilpatrick & Johns, 2003).

The complex interactions between the seven independent, but often interrelated 1) environmental; 2) biological; 3) chemical; 4) economic; 5) technical; 6) political; and 7) social systems, affect the management of a farming business (Fulton & Vanclay, 2011). However, this complexity is often oversimplified by the use of an overarching term; for example, the operation of seeding (planting a crop). To a non-farmer, seeding may be considered a single task of placing the seed in the ground. In reality, the term embraces a process consisting of multiple tasks: selecting an appropriate crop type and variety; sourcing and transporting; and making decisions about seed rate, seed depth and time of sowing in relation to seasonal conditions, logistics and biological requirements. Other tasks include pre- and post-seeding weed control and crop nutrition, and mechanical considerations including choice of soil opener, tine, seeding system, and tools for stubble management and post-seeding soil treatment (Ashworth & Tola, 2010; Grains Research and Development Corporation, Grains Research and Development Corporation, 2017). Each task is influenced by one or more of the seven systems. Decisions may relate to a task or influence multiple tasks and, for broadacre farming where control over the environment is limited, choices may change with location across the farm and weather conditions.

Many sensors and controllers enable the seeding operation, including rate and depth controllers, and autosteer and guidance, which combine to regulate inputs and seed by location. However, decisions behind physical operations—including the determination of input rates in relation to variety, location and yield, and quality parameters—continue to be based on a combination of observation, history, rules of thumb and decision support tools (DSTs) that require information to be uploaded manually (Grains Research and Development Corporation, 2017; McCown et al., 2002). Seeding is just one of many complex on-farm processes that could benefit hugely from digitalisation. Weed management is another, as depicted by Wilson et al. (2009), who identify five decision pathways and a potential of 33 choices of action. Digitalisation of agricultural tasks and processes requires appropriate and interoperable datasets, data analysis systems and connectivity solutions, as well as appropriate legislation (Trindall et al., 2018).

2.1.3 Defining Digital Agriculture

From the discussion so far, it is easy to see DA as a combination of two multifaceted, complex ecosystems—but what is meant by DA? DA is synonymous with the terms digital farming, smart farming (Ayre et al., 2019; Kruize et al., 2016; Pivoto et al., 2018; Wolfert et al., 2017) and decision agriculture (Lamb, 2017; Trindall et al., 2018). It is also encapsulated within the term Agriculture 4.0 (De Clercq et al., 2018; Trendov et al., 2019(Barrett & Rose, 2022)). The ‘4.0’ in Agriculture 4.0 signifies the fourth wave in the agricultural technology revolution—the first being mechanisation, the second agricultural chemistry and the third precision farming, which incorporated biological advances, genetics and the Global Navigation Satellite System (GNSS) (Trendov et al., 2019; Zuckerberg, 2017). Each wave has brought monumental changes—more recently termed disruption, as the new innovations displace long standing incumbent technologies —across agri-food industries. Each change is refined and tailored to the needs of different industry sectors, regions and production systems. However, Agriculture 4.0 goes beyond the definition of DA by including concepts such as desert agriculture and seawater farming, cultured meat and 3D printing of food (De Clercq et al., 2018), thus representing disruption to achieve full digital transformation (Savic, 2019) (Figure 2.1).

The DA ecosystem gathers, interprets, acts on and shares data along the whole value chain—before, behind and beyond the farm gate (Figure 2.2). This is achieved using interconnected systems including proximal and remote sensors that collect data using common data standards and language; analytical programs and applications (‘apps’) that interpret data against standards and norms; systems for data storage and transmission; and ICT to implement decisions and actions (Barry et al., 2017; Lamb, 2017).

Farming businesses already collect and use data; DA offers the opportunity to integrate, analyse and generate actions from these data in new and improved ways, although it introduces increased complexity. For example, a conventional livestock ear tag shows an animal’s unique identification number; good eyesight and being physically close enough to read the tag are the only requirement to use such a tag. If one upgrades to a digital ear tag, every animal on farm can be located remotely, activity can be tracked and individual animals can be managed according to health, nutrition or security parameters (Henry et al., 2012). However, use of digital ear tags requires a power source, connection to the internet, analytical software and the skills to use the software to turn the data into actions (Bahlo et al., 2019).

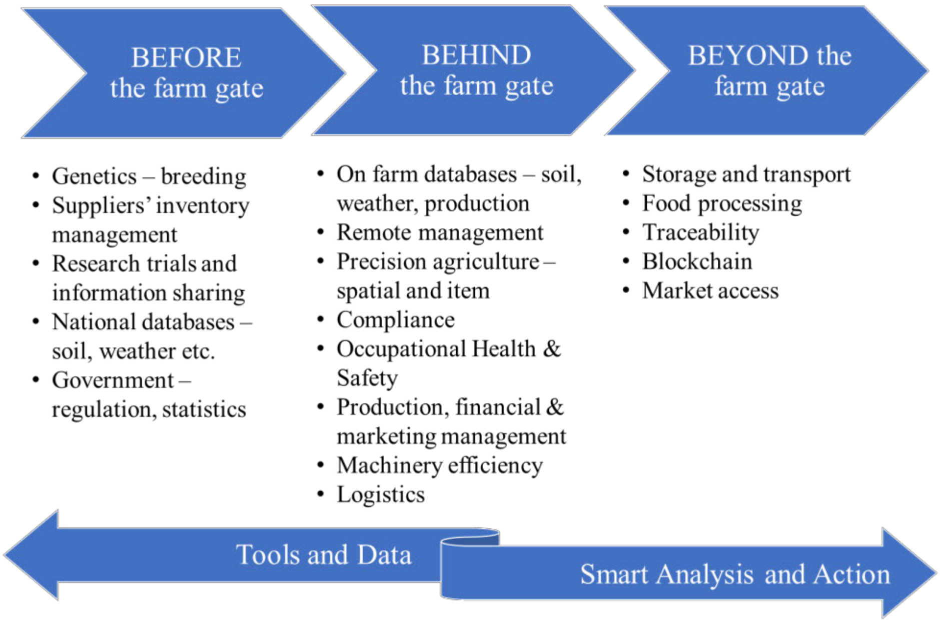


Figure 2.2

Components of an Integrated Digital Supply Chain for Grain Farming, Based on Barry et al. (2017)

The use of connected technology and interoperable datasets enables a continuous data loop through planning, measuring, action and reviewing activities, to improve productivity, efficiency and traceability; thus creating a digitalised value chain (Ayre et al., 2019; Barry et al., 2017; De Clercq et al., 2018; Evans et al., 2017; Klerkx et al., 2019; Trendov et al., 2019).

In agriculture, digital technologies are divided into two major groupings: those with embodied knowledge and those that are information rich (Griffin et al., 2017). These groupings are based on how the user interacts with data. For embodied-knowledge technologies, the collection and analysis of data requires minimal operator intervention. Technologies such as automated guidance or animal identification systems, section control and automated product grading systems are examples of embodied-knowledge technologies. Information-rich technologies require the user to have the skills to combine the data gathered with other datasets, and then to analyse the new dataset to support decisions and actions (Miller et al., 2018). Varying an input rate by production unit or assessing stock on hand in regard to inputs required are examples of information-rich technologies. As technology evolves and automation increases, technologies that are currently classified as information intensive may evolve into embodied knowledge. An example of this is upgrading of an automated flood irrigation system to a smart system through the addition of artificial intelligence systems to predict plant water requirement, calculate water rates and control water application (Wang et al., 2020).

Although precision farming (also referred to as PA) preceded DA, aspects of the third wave in the agricultural technology revolution, including the spatial management of inputs and outputs in broadacre farming (Miller et al., 2018) and unit or site-specific management of broadacre livestock (Bahlo et al., 2019), can now be viewed as a subset of DA activities (Figure 2.2). These aspects of PA are information intensive; for example, variable rate inputs that require data on the past, present and future situation to implement site- or unit-specific actions (Griffin et al., 2017). The definition of PA released by the International Society of Precision Agriculture in 2019 reflects this creep of PA into DA, while emphasising the operational aspects of PA's place in the digital value chain.

PA is a management strategy that gathers, processes and analyses temporal, spatial and individual data and combines them with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production (International Society of Precision Agriculture, 2019, About ISPA, para. 1).

2.1.3.1 Digital Agriculture Maturity

Despite the inexorable evolution of every facet of our lives into the digital realm, the last 20 years have demonstrated that the metamorphosis from ICT to DA has been easier said than done (Lowenberg-DeBoer & Erickson, 2019). Agriculture is recorded as one of the least digitalised industry sectors across the developed world (Blackburn et al., 2017; Bughin et al., 2016; Manyika et al., 2015). The maturity of digital ecosystems has been represented using a capability maturity model (CMM) (Humphrey, 1988, p. 74) that consists of five stages: 1) initial or ad hoc; 2) repeatable; 3) defined; 4) managed; and 5) optimising, with each step supported by a detailed definition.

Despite rapid evolution, the digitalisation of agriculture, both on and off farm, is relatively immature (Ayre et al., 2019; Janssen et al., 2017; Pierpaoli et al., 2013; Trindall et al., 2018; Wolfert et al., 2017). Several researchers have suggested it is at the earliest stage of maturity—ad hoc (Rijswijk et al., 2019; Skinner et al., 2017). Until fundamental issues including connectivity (Lamb, 2017; Marshall et al., 2020), common data standards (Bahlo et al., 2019; Skinner et al., 2017) and outputs from data analytics that support on-farm actions (Bahlo et al., 2019; Barry et al., 2017; Evans et al., 2017) are resolved, the maturity of DA systems will be limited. The development of appropriate end-to-end solutions can only be achieved with maturity. Such developments will reduce fragmentation and harmonise the elements of the digitalised value chain (Jakku et al., 2019; Skinner et al., 2017; Trendov et al., 2019). At the current stage of immaturity, farming businesses remain unclear of the value proposition of digitalisation and are often cautious and confused about what, how and when to capitalise on the potential advantages of digital technologies (Kernecker et al., 2020; Relf-Eckstein et al., 2019; Skinner et al., 2017).

2.1.4 Summary Section 2.1

The terms digital and agriculture each represent diverse and complex systems, but together as DA, they incorporate a new lexicon of meanings. These range from the conversion from analogue to digital data; to interconnected computers using interoperable datasets to perform analysis and digital administration processes; and the digital transformation of systems using artificial intelligence and automation. An appreciation of these three elements—digitised, digitalised and digitally transformed—helps deconstruct the single term DA. Because of the immaturity of this industry sector, clarity around the true value propositions for developers and adopters along the value chain is often lacking.

2.2 Potential of Digital Agriculture—Why Change?

'Digital—the way of the future', was a catch cry of the late 20th century. Despite this, more than 20 years into the 21st century, much of the promise of digitalisation has yet to be delivered, especially in rural and remote regions of Australia, and consequently to agriculture (Marshall et al., 2020). This failure centres on the tyranny of distance and low population density, creating challenges for the supply of telecommunications solutions that provide connectivity, a critical enabler of digital (Dufty & Jackson, 2018; Trendov et al., 2019; Zhang et al., 2017). However, the failure of agriculture to capture the potential of digitalisation is greater than just a lack of connectivity. In many situations across the globe it appears that the potential of DA has been oversold relative to the rate of delivery of solutions with concrete value propositions (Bacco et al., 2019; Perrett et al., 2017; Robertson et al., 2012). This positive perspective has been embraced by the media and policy makers across the globe, with little critical reflection or analysis of other approaches or on-farm priorities (Barrett & Rose, 2022).

Irrespective of these failings, the potential for digitalisation of agriculture remains. The ‘push–pull’ mechanisms driving the development and adoption of DA can be associated with four groups of actors: governments and institutions; investors and developers; customers and consumers; and on-farm users (Table 2.1). Push factors driving government support for DA include international concerns over food security and managing the environment, against a background of the need to increase productivity from limited land and labour (Trendov et al., 2019). Concurrently, consumers make increasing demands for ethical production and greater transparency and traceability in the supply chain (Fountas et al., 2015; Lappo et al., 2015). The pull factors relate to opportunities provided to developers and users from improved mobile communications and broadband access, customer demand for novel production systems, and on-farm need for improved productivity and to bridge the disconnect between producers and consumers (Leonard et al., 2017; Perrett et al., 2017). At times it can be difficult to disentangle the push from the pull factors because they are intimately linked, delivering win–win solutions for multiple actors; together they are manoeuvring agriculture to a new normal.

Table 2.1

Push and Pull Factors by Actor Driving Digital Change in Agriculture (based on AgFunder, 2020; Lappo et al., 2015; Perrett et al., 2017; Trendov et al., 2019)

	Actor	Push	Pull
1	National governments, international institutions	Food security, environmental sustainability	Investment Industry development
2	Investors and developers	Productivity gains Disruptive opportunities Demand along the value chain	Investment opportunities Underdeveloped market Opportunities from ubiquitous connectivity
3	Customers and consumers	Traceability and trackability Sustainability Ethical production	Food security Novel production systems
4	On-farm users, including farming, suppliers and service industries	Increased compliance Greater disconnect between consumers and producers	Improved efficiency, productivity and profitability

2.2.1 Government and Institutions

Food security, environmental sustainability and improving on-farm productivity are central tenets of government support for the digital transformation of agriculture. The weight placed on each of these push factors varies among the regions represented. A global perspective is provided by the United Nations (UN) Food and Agriculture Organisation (FAO), which sees agricultural development and the use of digital solutions in both developed and developing countries as central to meeting its 'Sustainable Development Goals' (SDG) for ending poverty and hunger (Trendov et al., 2019) (Figure 2.3). Goal 15, about 'life on land', is the only one specific to agriculture, yet most of the 17 goals have some relationship to agriculture through the aim for food security; and Goal 9 relating to 'industry, innovation and infrastructure', through new technology. E-agriculture, that is production systems supported by the ubiquitous availability of information and connected through mobile communications, is a key thrust of FAO investment into digital transformation. Through partnerships with national institutions, commercial companies and innovation start-ups, the FAO is helping to stimulate innovative digital solutions to meet the UN's SDGs (Trendov et al., 2019).

In contrast, the European Union's (EU's) focus on digitalisation primarily aims to mitigate environmental pressure, especially that associated with climate change, and the social issues impacting agriculture including rural depopulation and aging farming communities. Disparate opinions on the role of agri-innovation in the future of farming were identified depending on the policy sector from which they emanated (Barrett & Rose, 2022; Lajoie-O'Malley et al., 2020). The members of the EU stated that digital technologies such as robotics, precision farming, blockchain, the Internet of Things (IoT), fast broadband and high-performance computing can help transform agri-food markets, farming systems and businesses (European

Community, 2019). This can be achieved by supporting improved resilience, resource use and decision making to optimise all types of farming, enable better decisions and reshape the functioning of agri-food markets. As might be expected, with the UK's recent departure from the EU its strategy for agricultural technology was less about mitigating environment pressure and more about cost reduction, increased productivity, attracting new entrants and improving traceability (Barrett & Rose, 2022).

Figure 2.3

The United Nations Sustainable Development Goals to End Poverty and Hunger Underpin the Global Push for Digital Agriculture (United Nations, n.d)

In developed nations, including the United States of America (USA), Canada and Australia, governments are able to prioritise food exports and food waste over hunger and food security. Consequently, the government push for DA is focussed on productivity growth (Dufty & Jackson, 2018). In these countries, digitalisation and digital transformation are less frequently proposed as solutions for sustainability or environmental management. For example, in the most recent Australian Government report considering on-farm practice change to reduce agriculture's environmental impact and increase its sustainability, there are no references to technology, PA or digitalisation (Barson et al., 2012). This ignores the fact that PA technologies (already adopted in Australia) help improve the targeting of inputs to weather and crop demand, reducing waste and damage to off-target species; and reflects no vision for the future use of DA on farm.

Irrespective of government or institution minimal critical analysis, opinion or statements were found relating to potential negative consequences of adopting digital agriculture. Where they occurred, they were more related to lost opportunity than negative impacts, with the exception of recognising the need for increased cyber security (Barrett & Rose, 2022; Lajoie-O'Malley et al., 2020).

The industries involved in the development of digital technologies for agriculture are colloquially referred to as agtech and foodtech. Both areas of new technology development are attracting considerable investment from venture capitalists and business start-up funds. This creation of income flows and employment are also major pull factors for government involvement in, and promotion of, the digitalisation of agriculture. In Australia, this investment is highlighted by government desire to develop integrated industry solutions, as illustrated by support for activities such as the Cooperative Research Centre for Food Agility (CRC FA; www.foodagility.com). Across the globe, government enthusiasm for the use of digital technologies in agriculture can only be based on evidence from other industry sectors because uptake in agriculture, compared with other sectors, is low (Blackburn et al., 2017; Bughin et al., 2016; Manyika et al., 2015; Miller et al., 2018; Zhang et al., 2017). However, governments cannot expect to reap the potential of DA without implementing supportive policies. Many researchers have identified that successful digitalisation requires supportive government policy in areas of leadership; research, development and extension investment; legislation; and data provision (Relf-Eckstein et al., 2019; Sunding & Zilberman, 2001; Trindall et al., 2018).

2.2.2 Investors and Developers

The threats of food scarcity, climate change and plateauing productivity, which have encouraged government and institutional interest in DA, also provide opportunities for investors and developers (De Clercq et al., 2018; Trendov et al., 2019). The combination of these global challenges with the predicted financial opportunities related to unconstrained digitalisation along the agri-food value chain (Perrett et al., 2017), and the fact that agricultural adoption of technology trails behind other industry sectors (Blackburn et al., 2017; Bughin et al., 2016; Manyika et al., 2015), has resulted in a frenzy of investment in ag- and foodtech.

The agtech and foodtech venture capital fund AgFunder, reported a 370% growth in farm tech start-ups between 2013 and 2019, with peak investment of US$4.7 billion in 2019 (AgFunder, 2020). This represented 6.8% growth compared with the previous year and reported positively against the 16% shrinkage in other venture capital sectors. Enthusiasm for agtech and foodtech has attracted investment from non-traditional players in agriculture, including Google and Bosch (AgFunder, 2020). However, it has been reported that some regions have shown significant contraction in investments. The situation in China, which reported a 78% contraction in funding between 2018 and 2020, suggests that financial returns from agtech and foodtech investments are not guaranteed (AgFunder, 2020).

Much of the substantial capital investment has been in novel farming systems, such as insect protein production, rather than in tools to support the digitalisation of current farming systems (AgFunder, 2020). In the area of on-farm digital transformation, some of the largest investments have been from long-term suppliers to agricultural industries. Currently, most commercialised agtech is focussed on digitisation of developed agricultural production sectors such as broadacre cropping (Bronson, 2019). There are examples of established suppliers buying out creators of disruptive technologies, which can influence the rate of transformation to digital (AgFunder, 2020; Klerkx et al., 2019; Relf-Eckstein et al., 2019; Trendov et al., 2019). In contrast, investment in digitalisation for novel and niche food production systems remains a significant area for start-up investment (AgFunder, 2020).

This combination of governments' strategic push and the pull of predicted financial returns is encouraging significant interest in the agtech and foodtech sectors from suppliers of professional services and advice. Global players in business development including Accenture, Deloitte, KPMG, Ernst & Young and McKinsey all now offer services relating to DA (Blackburn et al., 2017; Bughin et al., 2016; Cotton Research and Development Corporation, Cotton Research and Development Corporation, 2019; De Clercq et al., 2018; Manyika et al., 2015). In the eyes of the investment services and corporate management world, agriculture is evolving from a low-tech, low-opportunity industry to a major investment opportunity.

While investment in the agtech and foodtech areas continues to grow, the sector remains volatile. Investors are often looking for quick returns; some are bound to be disappointed. It seems many start-ups are pulled along by enthusiasm for the agri-food sector of venture capitalists with little knowledge or contact with their potential market (Barry et al., 2017; Kernecker et al., 2020; Relf-Eckstein et al., 2019; Robertson et al., 2012). Consequently, some agtech start-ups have already pivoted out of agriculture to other market sectors (AgFunder, 2020). Misinterpreting the drivers of on-farm change is not a problem unique to digitalisation. It has even been observed for research and advisory bodies embedded within agriculture (Kaine et al., 2011), but this lack of understanding of agriculture by developers can be viewed as another form of digital divide and barrier to the communication of clear value propositions (Lamb, 2017).

2.2.3 Customers and Consumers

The agricultural supply chain generally consists of multiple customers and actors sitting between the farm gate and the consumer's plate. For example, for the basic commodity of a loaf of bread, there are at least four customers—grain buyer, flour miller, baker, retailer—between the farmer and the consumer. In addition, between each of these customers there is transport and storage, making product traceability and trackability extremely complex, especially for bulk commodities (Klerkx et al., 2019; Wolfert et al., 2017). Digital transformation of current and new systems using blockchain and connected systems offers benefits in terms of logistics (Jakku et al., 2019) and more effective methods of traceability and trackability, which is especially attractive to customers and consumers (Fountas et al., 2015; Trendov et al., 2019).

Digital systems on farm and embedded in the supply chain offer customers and consumers a virtual connection with a producer. They enable farm businesses to demonstrate compliance with animal welfare and environmental legislation, and to meet consumer demand for ethical and environmentally responsible products (Relf-Eckstein et al., 2019; Rijswijk et al., 2019). Environmental responsibility has been driven by organic production but is increasingly linked to production systems that use resources responsibly, minimise waste and have a low carbon footprint, all of which can be supported by digital technologies (Lappo et al., 2015). New technologies, including digital, can help address consumer concerns and educate them at many points along the supply chain, including on farm, yet consumer distrust has been strongly associated with innovation and new technology. Because of lack of understanding of these new technologies, this consumer distrust can spill over into the systems working to help meet their demand for ethical and environmentally responsible food production (Lappo et al., 2015).

The repercussions of the agricultural and food industry not fully participating in the digital revolution are expected to resonate along the whole global supply chain, from the perspective of lost economic potential, efficiency and market access, and failing consumer confidence (Marshall et al., 2020; Perrett et al., 2017; Wolfert et al., 2010). Digital technologies can offer disruption and opportunities to new actors in the supply chain, but may also strengthen the position of major actors who may have a greater ability to change and support the adoption of new technologies (Klerkx et al.,2019). Similarly, they offer opportunities for farming and food industries to deliver on customer demands for ethical and sustainable production systems. However, careful communication and consumer education are required to avoid rejection based on misunderstanding and ignorance.

2.2.4 Users

Suppliers of on-farm products and service, before the farm gate, as well as the farming business, have all glimpsed the potential of digital since the introduction of internet and mobile services. In Australia, mobile phones, the internet, and tools such as internet banking and weather apps have all been widely adopted (Dufty & Jackson, 2018; Zhang et al., 2017). Indeed, the overall concept of digitisation is perceived to be useful and offering ways to improve practice, process and workload (Eastwood et al., 2019; Kernecker et al., 2020; Miller et al., 2018). However, the value proposition for specific digital offerings that enable digitalisation of production and associated practices is often lacking (Bacco et al., 2019; Klerkx et al., 2019; Llewellyn, 2014; Rijswijk et al., 2019; Say et al., 2017). Too often, digital is presented as a potential rather than proven value. For example, Perrett et al. (2017, p. 25) stated, ‘the unconstrained implementation of decision agriculture [in Australia] would result in a lift in the gross value of agri-food production of $19.1 billion’. This economic analysis was one of five parallel research projects from which

Leonard et al. (2017) summarised six significant areas of constraint to the digitalisation of agriculture in Australia:

- trust and legal issues around data and the use of disruptive technologies
- the need for universal, reliable connectivity
- lack of clear value propositions for users
- digital literacy across the value chain
- availability of appropriate data
- a need for platforms for data analytics and DSTs.

Innovations are more likely to be adopted if they are seen as profitable (Fountas et al., 2015; Hall & Khan, 2003; Rijswijk et al., 2019). However, value proposition is more than economic, and it can be specific to sector, region and farming business, especially when the business is run by a family (Fulton & Vanclay, 2011; Kuehne et al., 2011; Yule & Wood). For example, a family farm might value practices that support the passage of the farm to the next generation, which can include systems that help maintain stable cashflow rather than maximise profit and minimise borrowing (Vanclay, 2011). Value can relate to ease of use, usefulness, mitigation of risk and improved production (Adams et al., 2017; Evans et al., 2017; Pierpaoli et al., 2013; Vanclay, 2011). Technology developers need to understand the different attitudes to value between corporate and family farming business structures as well as between farming sectors and regions, if they are to produce solutions that provide relative advantage over incumbent solutions (Kaine et al., 2011; Rogers, 2003). Similarly, it cannot be assumed that motivations and perceptions of the potential for digitisation held by farming businesses align with those of governments and institutions. Kernecker et al. (2020) found that farmers in the EU were ambivalent about the potential of smart farming technologies to improve farm impacts on nature, a key driver of the EU's declaration on DA (European Community, 2019).

It has been proposed by many scholars that agriculture of the future will be digitally enhanced at all stages of production, from primary breeding and production, to processing and logistics, and finally to the consumer (Ayre et al., 2019; Barry et al., 2017; De Clercq et al., 2018). However, much research and investment has been dedicated to digitalisation of on-farm practices using sensors, data and precision technology; not through the whole value chain (Klerkx et al., 2019). Little in the literature addressees the data needs of farm advisers or the challenges of digitalisation faced by current businesses servicing agriculture before, behind or beyond the farm gate (Ayre et al., 2019; Eastwood et al., 2019). In addition, the majority of digital solutions in development are not disruptive but designed to blend with current production systems to make them less challenging for current users (Bronson, 2019). While digital changes remain held in silos and not integrated along the value chain, the desire for change by multiple actors along the chain will be limited, and the combined opportunities lost.

2.2.5 Summary Section 2.2

The development of new agtech and foodtech industries and digital solutions is being driven by the push and pull of potential advantages envisaged by four groups of actors. Ultimately, digital change will only occur if adoption occurs on farm, which supports the rational for the focus of this thesis to relate to on-farm adoption. Each group of actors has its own specific wants and needs from digital. A lack of conduits between the groups is creating digital divides between investors and potential markets, and government and on-farm perspectives of the value of investing in digital technologies. The lack of clear value proposition is just one of six key barriers that need to be addressed, if unconstrained digital transformation of the agricultural sector is to occur. Equally value proposition could be said to be impacted by the other five barriers making it foundational to the decision to adopt DA.

2.3 On-farm Adoption

In this section, on-farm adoption from the perspective of the technologies of interest, PA and DA, is discussed. Australia is recognised as a nation of early adopters of ICT (Lowenberg-DeBoer & Erickson, 2019; Trendov et al., 2019, p. 26). Globally, Australian farmers are also respected for their innovation in PA, especially for developing the first automated tractor guidance and steering system (Lowenberg-DeBoer & Erickson, 2019; Say et al., 2017). Fourteen years after the commercial launch of the Global Positioning System (GPS) in 1998, 77% of Australian grain growers were using the autosteer technology for vehicle guidance (Llewellyn, 2014; Robertson et al., 2012). Five years later, this figure had increased to 84%, second only to that for farmers in the USA (Table 2.2).

GNSS technologies not only underpin machine guidance and autosteer, but are vital for on-harvester grain monitoring with simultaneous capability for yield and quality mapping, and the spatial control of inputs (Bramley & Ouzman, 2019; Llewellyn, 2014; Lowenberg-DeBoer & Erickson, 2019; Miller et al., 2017). Beyond the high uptake of autosteer, Australian adoption of yield monitoring and associated PA technologies has been less enthusiastic. Table 2.2 illustrates uptake of these different technologies across regions based on use by grain producers.

Table 2.2

PA Adoption in Broadacre Grain Production by Country, Year and Technology (Lowenberg-DeBoer & Erickson, 2019)

Country	Year	GNSS guidance	Yield monitor	VRT inputs	GNSS linked soil testing	Electroconductivity soil mapping	Remote sensing imagery
Argentina	2018	60%	78%	42%	51%	26%	80%
Canada	2017	79%	48%	48%	43%	19%	28%
USA	2017	91%	93%	73%	66%	NA	56%
Australia	2017	84%	50%	52%	NA	26%	40%
UK	2016	20%	13%	14%	15%	NA	NA
Turkey	2015	5%	3%	0%	0%	NA	0%

Note. NA, not available; GNSS, Global Navigation Satellite System; VRT, variable rate technology.

Because of this limited uptake of PA technologies and low use of big data by Australian farming businesses, adoption of DA is considered slow and immature compared with in countries such as the USA and Israel (Ayre et al., 2019; Bacco et al., 2019; Rijswijk et al., 2019; Skinner et al., 2017). This variation in adoption between technologies and regions reflects the repeated argument that uptake of a new technology must be considered in context—not just in terms of the farmer—but in terms of the whole farming business (Evans et al., 2017; Kaine et al., 2011; Kernecker et al., 2020; Newton et al., 2020).

2.3.1 Adoption Theory

The potential influences on adoption or non-adoption of DA by farming businesses are explained by technology diffusion and adoption theory. Eight areas of diffusion research have been identified, from earliness of knowing about innovations, through to research on the consequences of innovation (Rogers, 2003). This thesis is focussed on diffusion theory in relation to rate of adoption of a different innovation in a social system as categorised by Rogers (2003, p. 96). Several models have been developed to address this perspective on adoption.

In a review of four such technology adoption models—1) Roger's innovation diffusion theory; 2) concerns-based adoption model; 3) technology acceptance model (TAM); and 4) united theory of acceptance and use of technology—Straub (2009, p. 626) concluded:

> technology adoption is a complex, inherently social, developmental process; individuals construct unique (but malleable) perceptions of technology that influence the adoption process; and successfully facilitating a technology adoption needs to address cognitive, emotional and contextual concerns.

The TAM has been used to assess PA adoption (Pierpaoli et al., 2013). Although it is accepted as the leading model for understanding technology adoption, it was designed to assess organisational adoption, and its relevance to household consumers has been questioned (Adams et al., 2017). This is relevant because family farming businesses are considered to behave more like consumers than corporate purchasers by changing only to meet their personal goals, which may not align with the goals of the business (Kaine et al., 2011; Vanclay, 2011). In contrast, diffusion of innovation theory was initiated via studies of rural sociology; in particular research on the diffusion of hybrid corn by Ryan and Goss, in 1943 (Rogers, 2003). Selecting a theory appropriate to family farming businesses—the target of this research—is important because people drive or impede adoption (Kane, 2019). In addition, farmers have a history of modifying machinery, and 'will to a large extent adapt a technology to their own situation' (Yule & Wood, p. 5).

Each of these four models places greater or lesser emphasis on the role of the technology and the role of the individual. Establishing this relationship between the human and technological elements of adoption in a specific situation helps clarify the value proposition for adoption by specific populations (Adams et al., 2017; Rogers, 2003). Diffusion of innovation theory lays out three feature sets that influence innovation uptake (Figure 2.4). The decision to adopt is based on five sequential stages, while the perception of attributes can occur in any order over time.

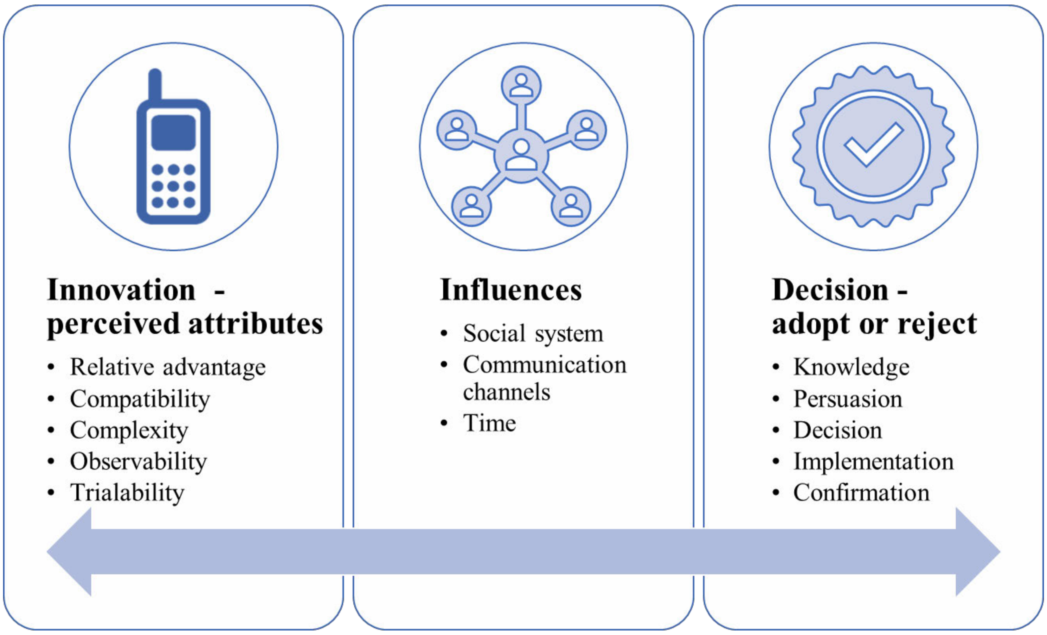


Figure 2.4

The Three Feature Sets that Influence Adoption Based on Rogers (2003)

2.3.1.1 Rate of Adoption

Prediction of adoption falls within the domain of marketing tradition, using such tools as the Bass prediction model (Rogers, 2003). However, prediction of future trends, often based on qualification and quantification of historic actions, is also the domain of data science and the behavioural science of market research (Rogers, 2003). Irrespective of which field of research is referenced, predicting the rate of adoption of a specific technology in different social systems provides valuable insights for those funding, developing, commercialising and extending technologies.

The ADOPT model developed by Kuehne et al. (2011) is a predictive model specific to the adoption of agricultural technology. This model extrapolates the hierarchy of effects from diffusion of innovation theory to provide a relatively fast and repeatable approach to quantify peak adoption in terms of duration and total potential users. The target audience for the ADOPT model is research organisations and businesses taking agricultural technology to farm business. The model is anchored to agriculture through reference to the social principles of on-farm adoption laid out by Vanclay (2011). The ADOPT model continues to promote adoption as a binary decision and cannot address the fact that a technology may be adopted in a trail phase or completely but then rejected.

2.3.2 The Limitations of Adoption Research

Research based on diffusion of innovation theory enables questions to be addressed about what technology has or has not been adopted, by whom and why. It cannot predict adoption and only through retrospective analysis can it help guide the adoption process; yet the theory is not flawless, and these limitations need to be recognised before implementation, to help avoidance.

A well-documented failing of adoption research is that adoption is framed as a binary, single, irreversible action, occurring at a moment in time (Rogers, 2003).A parallel issue is that relevant studies have failed to clearly differentiate between partial and complete adoption (Wilkinson, 2011). In reality, adoption by an individual takes time, may occur in several steps and can be reversed if a technology fails to deliver (Montes de Oca Munguia et al., 2021).

Diffusion of innovation theory does acknowledge that it takes time for a population to adopt, but it implies that with more exposure to positive value propositions adoption will automatically occur (Rogers, 2003), suggesting the attributes of the technology override individual’s preferences. This supposition fails on three counts: by ignoring the context of the value proposition; by overlooking that farming businesses have different perceptions of relative advantage; and by failing to acknowledge that adoption across the whole population is unlikely or takes considerable time (Kaine et al., 2011; Kuehne et al., 2011; Tey & Brindal, 2012). In a similar vein, the value propositions proposed are often fixed, which reflects neither the variability of financial returns nor the preference of farming businesses to innovate and improvise (McKenzie, 2013; Newton et al., 2020; Yule & Wood). Vanclay (2011) clearly lays out 27 principles that need to be considered when trying to facilitate on-farm adoption, and reinforces the individualist human aspects that mean that non-adoption can be a sensible strategy because of barriers such as lack of funds, skills or time.

2.3.3 Learnings from Precision Agriculture Adoption

Because of the immature and ad hoc adoption of DA (Jakku et al., 2019; Skinner et al., 2017), the adoption literature is limited. The few relevant studies focussed on PA rather than true digitalised processes or digital transformation (Klerkx et al., 2019). In contrast, numerous studies on adoption of PA have occurred, especially in the grain and grape production sectors. Based on research in these areas, and on the few papers regarding the uptake of precision technologies in livestock and horticulture, four groups of factors have been identified to influence PA adoption:

- agro-ecological
- socio-economic
- technology
- institutional.

The institutional factors were discussed in Section 2.2, so the following sections focus on the first three factors.

2.3.4 Agro-ecological Factors

In an analysis of 10 studies of grain growers (nine from the USA and one from Australia) regarding significant factors influencing the adoption of PA technologies, Tey and Brindal (2012) found good soil quality was a significant driver of adoption, while factors such as farm size, degree of specialisation, ownership structure and yield all influenced adoption. In a more recent study of farmers' experiences with smart farming technology, Kernecker et al. (2020) found significant differences in adoption. These differences related to country, farm size and cropping system between 287 farmers from seven European countries operating across four cropping systems. A study from Australia found that farm size influenced access to yield maps, number of years of yield mapping and use of canopy sensors, in a survey involving farms of average size 2,500 hectares (ha) (Bramley & Ouzman, 2019). In this research, larger farms tended to adopt PA earlier and use a greater range of PA tools, with some regional differences in adoption of PA beyond guidance (Bramley & Ouzman, 2019). Regional differences/geography were also noted as a factor influencing adoption in a review by Pierpaoli et al. (2013) of 20 PA adoption studies, many of which were also reviewed by Tey and Brindal (2012). Despite this range of factors found to influence adoption of PA, larger farm size is the only agro-ecological factor consistently associated with the adoption of PA. However, interactions between farm size and other factors have been reported. For example, in Australia, owners of smaller farms were most likely to report lack of skills as constraining their ability to adopt ICT (Dufty & Jackson, 2018). Research from the United Kingdom (UK) suggests that robotic farming systems will decouple farm size from economic viability (Lowenberg-DeBoer et al., 2019). Consequently, farm size and DA adoption may not be as tightly bound as for the adoption of PA.

2.3.5 Socio-economic Factors

Socio-economic factors are potentially the greatest influencer of adoption, especially in the context of family farming businesses (Pannell et al., 2011). While the cost of technology and the economic operating environment influence the adoption decision, it is the characteristics of the individuals in a farming business and of their network of influencers that can positively or negatively sway their judgements and ensure the success or failure of implementation (Kane, 2019; Rogers, 2003). To achieve appropriate technology adoption and support, high priority must be given to understanding the socio-economic drivers for a family farming business looking to change.

2.3.5.1 Innovativeness and Risk

An innovative adopter actively explores new ideas and approaches. Rogers (2003) suggested that only 2.5% of any population fall into this high-risk taking category, with the remainder of the population divided between four classes: early adopter, early majority, late majority and laggard (Figure 2.5). There is some dissent about the finite use of these terms, as individuals can change over time (Wilkinson, 2011). An individual's innovativeness influences their perception of the potential attributes of a new technology, which includes the assessment of the characteristics of the technology in terms of benefits, ease of use and compatibility with current systems (Rogers, 2003). Both innovativeness and perception are subjective assessments, shaped by an individual's circumstances and their orientation to profit and risk (Kuehne et al., 2017), because change always brings exposure to risk (Sunding & Zilberman, 2001). As Wilkinson (2011, p. 41) reminded us, 'Innovativeness is only part of the story: context is critical'.

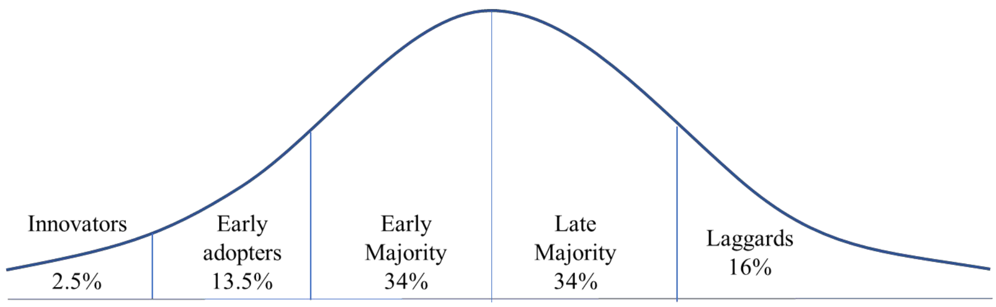


Figure 2.5

Adopter Categorisation on the Basis of Innovativeness (Rogers, 2003, p. 281)

Financial stability, culture and institutional factors such as free education can influence a user's degree of innovativeness, their attitude to technology and readiness to adopt

(Marshall et al., 2020; Pierpaoli et al., 2013; Say et al., 2017; Tey & Brindal, 2012). Education, training and farm profitability have all been linked to successfully changing production and management practices, not just in relation to PA (Kilpatrick, 2000). However, innovativeness can quickly change to disillusionment if an individual is constantly dealing with technology failures. Innovative adopters may cling to an early version of an innovation for too long, and late adopters may gain from their delayed adoption as a technology has been further developed and may have reduced in price (Wilkinson, 2011).

2.3.5.2 Age

Based on the adoption patterns for ICT in other industry sectors, there is often the assumption that younger farmers will be earlier adopters of PA and digital technology (Taylor & Silver, 2019), but this is not necessarily the case (Bramley & Ouzman, 2019; Zhang et al., 2017). Age is mentioned as a factor in many papers but there is no clear relationship with younger or older farmers (Pierpaoli et al., 2013; Zhang et al., 2017). Indeed, in the development of the ADOPT model, age was disregarded because of inconsistencies around age found in other technology adoption research (Kuehne et al., 2017). This lack of clear influence of age on technology adoption can be explained by the fact that stage in farming life and lifecycle of the family farm can be more influential than age alone (Vanclay, 2011). Formal education and current computer use are more significant indicators of PA adoption than is age (Tey & Brindal, 2012).

2.3.5.3 Farm Business Structure and Support Team

In Europe, the USA and Australia, most farming businesses are owned and run by families. Indeed, in Australia, 99% of the 85,000 farming businesses are family owned and on average directly employ only 3.5 staff members, while outsourcing some specialist production and management services (National Farmers Federation, 2017). Thus, it is understandable that much agricultural research focusses on the perspective of one member of the business, namely ‘the farmer’. Fulton and Vanclay

(2011) argued that all adoption needs to be considered from the perceptions of the family, farm and business, not just those of one individual, to establish the true effect of socio-economic factors on adoption. PA adoption research has lacked the family business contextualisation. When reporting from the perspective of the farmer, formal education and use of a consultant have been recorded as the most important factors influencing adoption, especially in family farming businesses (Llewellyn, 2014; Tey & Brindal, 2012). Other social factors recorded to influence decisions about PA adoption include farm ownership structures; satisfaction with current practices; current use of computers; and attitude to risk (Pierpaoli et al., 2013; Say et al., 2017; Tey & Brindal, 2012).

The use of multidisciplinary teams—primarily agronomic consultants—has been shown to be instrumental in the success of on-farm adoption of complex new technology, including for PA (Bramley & Ouzman, 2019; Eastwood et al., 2017; Llewellyn, 2014; Say et al., 2017; Tey & Brindal, 2012). Llewellyn (2014) found the significance of a consultant varied with choice of PA technology, and whether the business had already adopted PA or intended to in the future. While the use of multidisciplinary teams is considered supportive for each of the steps towards digital transformation, in many situations, the agronomic and management advisers accessed by farmers do not have the skills to support digital adoption. For example, in a survey of 1,000 producers across 17 industry sectors in Australia, Zhang et al. (2017) found that 53% of farming businesses used family members to help meet their telecommunication needs; a further 21% worked closely with a telecommunication service provider; and consultants played only a minor role. Indeed, agronomists and on-farm consultant have been found to be struggling to engage and deliver support using these disruptive technologies (Ayre et al., 2019; Eastwood et al., 2019). Building the skills and knowledge of advisers is necessary if they are to provide appropriate support in the use of technologies such as PA and DA (Eastwood et al., 2017). Education in technical and practical implementation of PA and DA for farmers, data scientists, agronomists and technicians has been highlighted as vital to accelerating adoption in Australia (Barry et al., 2017; Lamb, 2017).

2.3.5.4 Financial

Return on investment, perception of profitability and the current financial position of the farming business have been identified as financial factors of relevance to digital change (Pierpaoli et al., 2013; Say et al., 2017; Tey & Brindal, 2012; Zhang et al., 2017). Perception is a key phrase, as illustrated by Shockley et al. (2017, p. 724) who stated, 'When evaluating the economics of precision agriculture technologies (hardware, software or services), the results are as site-specific as the technology'. Perception of financial factors can be positive or negative. In a survey of farmers in the UK in 2013, 63% reported using PA to reduce input costs, while 47% reported they did not use PA because of high setup costs and it not being cost effective (Say et al., 2017). High cost also creates a barrier to the ability to test and trial a technology, which is an important factor in proving relative advantage (Kernecker et al., 2020; Rogers, 2003)

The perception that PA technology will improve profit supports positive adoption decisions (Tey & Brindal, 2012). However, the reality is not always realised, leading to lower profit expectations from current rather than potential users (Bramley & Ouzman, 2019; Kernecker et al., 2020; Llewellyn, 2014). Vanclay (2011) argued that improved profit alone will not drive adoption in family farming businesses because each business is influenced by its unique combination of socio-economic factors and values. He reminded us that the balance between risk and profit influence the motivation to change from an incumbent system: if risk is too high or profit potential too small, adoption will be low.

2.3.6 Technology

Economic conditions, rather than need, are considered strong drivers of the emergence of innovations (Sunding & Zilberman, 2001). However, 'need' is very different to 'want', and family farming businesses, which dominate by number in Australia, are driven by goals specific to each individual business and the people involved in that business. Indeed, between 49% and 87% of variation in the rate of adoption of innovations is influenced by the perception of a technology's attributes (Rogers, 2003, p. 221).

2.3.6.1 Perception of Advantage

Communication regarding the technology from both external sources and within a farmer's network is known to be key to adoption (Rogers, 2003), but this communication has to align the perceived attributes of the innovation with the values and goals of the farming business (Kaine et al., 2011; Pannell et al., 2011; Sewell et al., 2017; Vanclay, 2011). In Australia, farmers involved in dairy, broadacre and vegetable production reported lack of useful technologies as a barrier to adoption of ICT (Dufty & Jackson, 2018). Indeed, 20% of 2,200 participants in this survey reported 'nothing new of interest as inhibiting their uptake of new ICT tools' (Dufty & Jackson, 2018, p. 11). In the previous year, a smaller survey of 1,000 Australian producers from 17 production sectors revealed a lack of awareness of digital technologies (Zhang et al., 2017) and associated research noted, 'many competing products and conflicting messages to producers leading to confusion and [market] paralysis' (Skinner et al., 2017, p. 5).

2.3.6.2 Usefulness and Ease of Use

Research testing the role of new technology has rarely assessed each of the five perceived attributes (Figure 2.4), specifically or independently (Rogers, 2003). Relative advantage, for example, is often reported in terms of improved yield, productivity or profit, while issues of complexity and compatibility are either disregarded or rolled into statements regarding ease of use and usefulness (Bramley & Ouzman, 2019; Miller et al., 2018; Newton et al., 2020). In Europe, Kernecker et al. (2020) gathered feedback from current and potential adopters of smart farming tools in regard to perceptions of their usefulness. Improvement on previous tools and potential to improve work processes and workload received the highest ranking, considerably higher than the belief that the tools could improve farm income. This suggests that usefulness is much more than provision of financial and production value. In studies of household adoption of technology, Adams et al. (2017) found that perceived ease of use was not a significant factor because it was overridden by how compatible the technology was with lifestyle. This link between technology compatibility and lifestyle is an important consideration when assessing on-farm adoption, as family farming businesses behave more like non-specialist purchasers than organisational buyers (Kaine et al., 2011).

Pierpaoli et al. (2013) retrospectively assessed 20 studies of actual and potential PA adoption using a TAM. This work demonstrated that usefulness and ease of use were vital for technology adoption, provided this did not compromise cost of production. PA technologies that are easy to use, and generally cheaper and less sophisticated, were found to be preferred, often because of greater compatibility with current equipment, even if these technologies were considered less useful (Pierpaoli et al., 2013). In Australia, technical and data issues including loss of data, complexity of calibration and usefulness were the most cited factors to curtail adoption of PA—not lack of confidence in agronomic benefits (Robertson et al., 2012). Again, this demonstrates the fine balance between ease of use and usefulness of a technology in relation to adoption.

The requirement for new skills and the need to allocate time to developing these skills have been identified as barriers to the use of PA technologies, even when considered useful. The greater adoption of embodied-knowledge technologies, which are considered to require fewer skills than information-intensive technologies, aligns with the argument that if a technology is harder to use and requires additional skills, it is less likely to be adopted (Miller et al., 2018; Vanclay, 2011). As with other on-farm technologies, confidence regarding ease of use of PA is boosted by trials and expert support (Bramley & Ouzman, 2019; Marshall et al., 2020; Vanclay, 2011). Without such support and demonstration, high levels of knowledge and process development can be required from the farming business for on-farm implementation of a PA technology (Evans et al., 2017). As farmers are often time poor, the time needed to implement a new technology can be a barrier to adoption even with knowledge of the technology's usefulness (Dufty & Jackson, 2018); hence the importance of ease of use.

2.3.6.3 Compatibility, Interoperability and Reliability

Compatibility is one of Rogers's (2003) five perceived attributes (Figure 2.4) and is reported from several perspectives:

- technology's compatibility with current farming systems and skills, and knowledge of the operators (Kernecker et al., 2020; Robertson et al., 2012)
- incompatibility between PA hardware and software (Fountas et al., 2015; Kutter et al., 2011)
- interoperability, or lack of, between datasets (Evans et al., 2017).

The issue of incompatibility between brands, and even models from the same manufacturer, is a source of operator frustration and disillusionment (Kernecker et al., 2020; Rijswijk et al., 2019) as widely reported in the grey literature (Faleide, 2019; Leithold, 2019). Equipment incompatibility includes issues of software and hardware, and can be as simple as not having the correct ports or plugs (Jakku et al., 2019). Establishing a working digitalised system is one challenge; keeping it going can be another matter:

> at least 240 sensors would be resident on a new combine harvester, and upwards of 60 sensors on a new, large tractor typical of broadacre farming. There are many potential points of failure and sensors needing repair, replacement, or attention. (Relf-Eckstein et al., 2019, p. 3)

2.3.7 Summary of Section 2.3

The adoption process for DA was discussed based on the experience with PA. This was dissected with reference to three categories of factor:

- agro-ecological
- socio-economic
- technological.

Of the many agro-ecological factors researched, farm size was the only consistent influence. Social and behavioural issues including perception of a technology’s advantages, cost and usefulness were all found to contribute to the value proposition for PA and are likely to be influential in the uptake of DA, based on the diffusion of innovation theory. However, it is clear that the value proposition for individual farming businesses and the individuals within each business can vary considerably. Consequently, managing the interface between the need for technology as assumed by a business, and the acceptance of technology by the users, is crucial for adoption success and needs to be considered for a farming business as their situation will be unique.

The experience from the adoption of PA can be used as a compass for the route to adoption of DA. However, the additional technological challenges of connectivity and interoperable data, which are central to implementing DA, must be recognised, and are discussed in the next section.

2.4 Adoption Challenges Presented by Digital Agriculture

Digital systems combine embodied-knowledge and information-rich technologies but take them to the next level by providing integration across on-farm systems and with other parts of the value chain (Barry et al., 2017). To move from PA to a digitalised system requires two additional enablers: access to reliable communication networks (connectivity); and digitalised data that can be integrated with other datasets using a common formats and data language (Bahlo et al., 2019; Trendov et al., 2019). Both enablers, to some extent, are influenced by institutional factors and commercial factors beyond the control of the farming business, such as government communication policy, and software licences and data agreements (Trindall et al., 2018). For example, in Australia, the national broadband network (NBN) is provided by NBN Co. Ltd, a government-owned company, while the National Narrowband Network Co. is one of several privately owned, large providers of wide area networks for use with the IoT.

2.4.1 Connectivity

Digital inclusion and the use of advanced agtech demand digital connectivity (European Community, 2019; Lamb, 2017; Marshall et al., 2020; Trendov et al., 2019). Without reliable, cost-effective connectivity, agricultural industries are excluded from the potential offered by digital technologies. This is because digitalised agricultural systems consist of multiple, interacting bundles of technologies that share data across connected networks (Klerkx et al., 2019). In addition to a poor perception of the quality and reliability of rural connectivity, farming businesses struggle to comprehend connectivity options and requirements, because of their complexity (Leonard et al., 2017).

On-farm connectivity occurs at several scales, from proximal sharing of data using technologies such as Bluetooth to remote communication across a landscape via wired or wireless local area networks, or pan-global solutions via radio and satellite connections (Lamb, 2017). Connectivity is a misleadingly simplistic term, suggesting A joins to B. The reality is that connectivity requires multiple technologies including sensors; devices; computers; transmitters/receivers; hubs/nodes; antennae; and power sources, and can use four different communication solutions—satellite, cellular, cable and Wi-Fi—depending whether a fixed or mobile solution is required (Figure 2.6). Digital communication and connectivity on farm is certainly not a case of 'one size fits all'. Farming businesses and even whole regions often lack the knowledge and skills to capitalise on and implement digital connectivity solutions (Lamb, 2017).

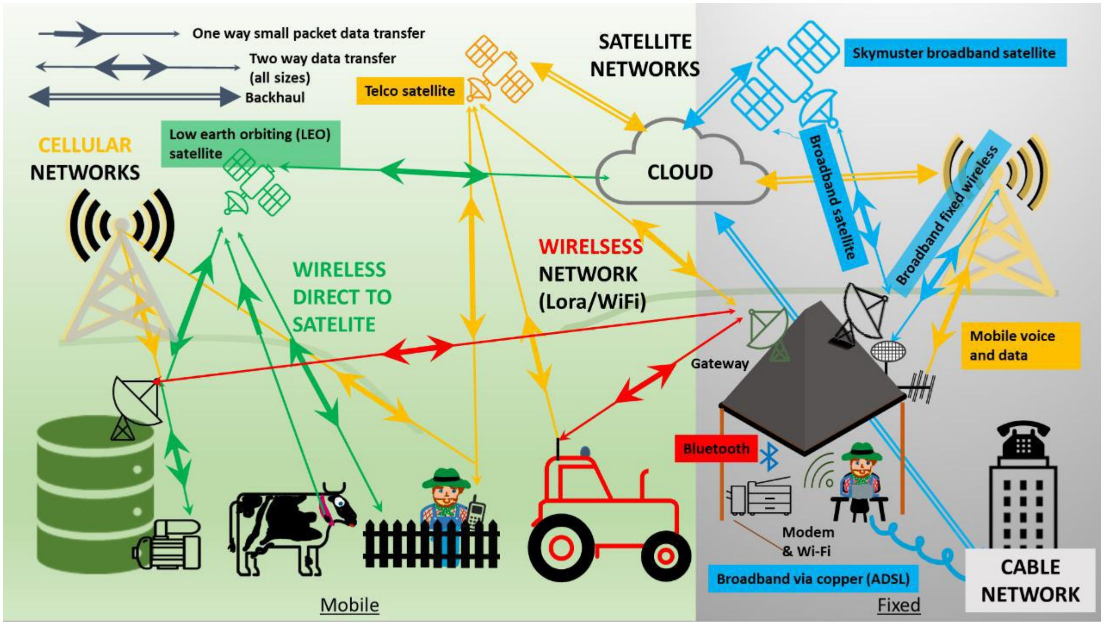


Figure 2.6

The Four Types of On-farm Communication Networks Based on Lamb (2017)

Note. Network key: blue = broadband, yellow = mobile/cellular, green = wireless satellite, red = wireless local.

To reach the farm office or the outside world, packets of data need to be transmitted via a communications network. There are four primary forms of network that transmit voice and data: satellite; cellular (also called mobile); wireless (often generically but incorrectly referred to as Wi-Fi, instead of the correct term wireless area network [WAN]); and cable (Lamb, 2017; Relf-Eckstein et al., 2019). Lamb (2017) described a telecommunications network as static (fixed) within a building or confined area; or mobile, allowing access across a landscape with multiple subnetworks (cable, satellite and cellular) working together linking communications across the globe (the access network). A backhaul network joins the telecommunications and access networks together. In a mobile network, the last link from the access network is wireless.

For voice and data communication, Australian farming businesses frequently subscribe to more than one of these connectivity networks (Dufty & Jackson, 2018; Zhang et al., 2017). A fifth network that is commonly subscribed to by farmers is for location services via GNSS (Bramley & Ouzman, 2019). In this section, it is the communication networks that are of interest. All of these networks are fundamental to the value of digital apps along the whole value chain (Barry et al., 2017; Bramley & Ouzman, 2019; Lamb, 2017; Relf-Eckstein et al., 2019; Zhang et al., 2017).

The array and complexity of connectivity solutions, the continuous development of communications products and capabilities, and the often low digital literacy on farm are all significant barriers to farming businesses changing to digital processes (Lamb, 2017). This lack of digital skills and support service is partly due to several of the networks being relatively immature but developing rapidly. For example, in Australia, the physical implementation of the NBN was announced in 2009, initiated in 2011, and 90% complete in 2020 (Communications Alliance Pty Ltd, n.d), yet large areas of the country continue to have limited access to reliable mobile coverage or broadband internet, other than from satellite. The tyranny of distance and low demand because of the sparse population result in broadband internet and cellular phone services that provide inferior reliability and transmission. This constraint was also noted by Relf-Eckstein et al. (2019) in the development on on-farm robots for broadacre cropping in Canada. While communication solutions continue to evolve, farmers' perceptions around lack of reliable connectivity persist (Zhang et al., 2017). This perception continues to limit the uptake of agricultural technologies associated with the collection and use of data (Lamb, 2017; Zhang et al., 2017).

2.4.2 Data Issues and the Adoption of Digital Agriculture

Digitised data are the driving force behind digitalisation and digital transformation. Wolfert et al. (2017) identified three sources of data generation in farming businesses or along the value chain: 1) humans; 2) machines; and 3) processes. On-farm data generation, especially from machines, is increasing exponentially (Skinner et al., 2017). Subscribers to specific farm management and telecommunications services have been reported to gather multiple gigabytes of data per hectare (Carolan, 2017). While many data are now being collected on farm, they are often used by agribusiness sector rather than on farm (Wolfert et al., 2017).

To truly reap the rewards of digital change, issues of data quality, interoperability of datasets and data ownership need to be addressed (Lamb, 2017). In addition, barriers to adoption of DA have been related to availability of data of sufficient quantity, quality and interoperability and the dearth of suitable data analysis systems to interpret data into actionable decisions (Bacco et al., 2019; Barry et al., 2017). In Australia, poor use of data and limited control over data are considered to disadvantage farming businesses (Skinner et al., 2017; Wiseman & Sanderson, 2017).

Consequently, a substantial hurdle for digital transformation in agriculture is the attitude of individuals and businesses to the collection and use of data (Bahlo et al., 2019; Bramley & Ouzman, 2019; Evans et al., 2017; Klerkx et al., 2019; Relf-Eckstein et al., 2019; Savic, 2019; Wolfert et al., 2017).

2.4.2.1 On-farm Attitude to Data

Farming businesses gather data for short-term (real time, daily to seasonal) and long-term (strategic, year on year) planning and activity, with the need to combine data from a range of sources aiming to gain multiple insights and uses (Newton et al., 2020). Many have reaped the rewards of big datasets generated by research and used in plant and animal breeding, and weather forecasting (Newton et al., 2020; Skinner et al., 2017), yet on-farm data are still often kept in handwritten, analogue formats or basic computer spreadsheets (Bramley & Ouzman, 2019; Skinner et al., 2017). Indeed, in a survey completed by 203 grain growers across Australia, Bramley and Ouzman (2019) found that 70% continued to manage their farm data on paper, without use of either a spreadsheet or dedicated farm management software. A 2017 (Zhang et al.) industry-wide survey of 1,000 Australian producers from 17 agricultural subsectors reported the predominance of paper-based rather than electronic storage of records. This was found for all record types, with the exception of financial data in the livestock industries; and yield, soil and financial data in the cropping sector (Zhang et al., 2017).

These traditional forms of data collection should not be underestimated because those already collecting and using data, irrespective of the format, are more likely to value additional and digital data (Bahlo et al., 2019; Newton et al., 2020; Zhang et al., 2017). However, the reality is that much on-farm production and management data are held in multiple formats and software. This fragmented approach to recording data results in inconsistency and difficulty in analysis and use

(Fountas et al., 2015; Jakku et al., 2019). Farmers have reported they would consider digital systems for data collection, storage and analysis if more integrated systems existed (Kernecker et al., 2020).

Variation in attitude and use of data exists among regions and industry sectors, and by age and gender. Among several regional differences noted in Europe, Fountas et al. (2015) found greater computer use by the more business-oriented northern European farmers than those in the south. The main method of data storage was on a terrestrial computer (Fountas et al., 2015) but this may change with the evolution of the cloud and improving on-farm connectivity.

In Australia, state differences in data collection, use and storage were reported by Zhang et al. (2017). For example, 63% of respondents from South Australia, but only 39% from Queensland, collected livestock breeding data. The reason for such differences were not explored but could relate to regional differences in production systems. Industry sector differences in recording and use of data were also found, with financial data being the only widely valued data source. Even these were only collected by 72% of crop producers and 79% of livestock producers, despite such data being required for taxation purposes. Livestock producers predominantly stored all data on farm rather than using cloud or service provider storage.

In terms of valuing data, Zhang et al. (2017) reported greater appreciation by younger farmers in broadacre livestock industries but no age relationship with data appreciation in broadacre cropping industries in Australia. These differences emphasise the need for contextualising data issues and the data culture in relation to a farming business's specific values and goals (Evans et al., 2017; Fulton & Vanclay, 2011). Skinner et al. (2017) addressed the maturity of seven pillars of big data success in relation to agriculture. Data culture is one of these and in Australia was reported to be ad hoc (Table 2.3). Indeed, in a parallel study by Zhang et al. (2017), it was reported that current use of data had little impact on the profit of a farming business, consistent with the ad hoc definition of Skinner et al. (2017).

Table 2.3

Maturity Criteria for Big Data Culture, One of the Seven Pillars of Big Data (Skinner et al., 2017)

	Ad hoc	Foundational	Competitive	Differentiating	Breakaway
Data culture	The application of analytical insight is the choice of the producer and has little effect on profit or the wider industry.	The producer is aware of the insights available from data produced on farm but is largely resistant to adaptation required to take advantage of the insight.	The producer makes limited farm management decisions using analytical insight to improve operational efficiency and generate additional profits.	Producers are well informed with insight from analytics, and the capable of acting to maximise resulting yield/profits.	The producer and value chain continuously adapt and improve, using analytical insight to support their strategic objectives.

Having data is one thing, putting them to use is another. Farmers say automated data collection systems could be highly informative but more data does not mean more data use, because of lack of time for analysis (Evans et al., 2017). Advisers and consultants are more likely to spend time on data analysis than are farmers, and to present results to their farmer clients to support farm production decisions (Ayre et al., 2019). Such work helps improve the perception of data by the farming business and the confidence in its use (Sewell et al., 2017). Too often, the DSTs, commonly used for data analysis in agriculture, provide a finite answer but not direction for action, creating disillusionment over their use (Evans et al., 2017; Long, 2013). Analytical tools to support decisions using integrated datasets are generally lacking in agriculture (Barry et al., 2017). However, data should not be confused with knowledge. To value data, users require the knowledge to be able to distinguish relevant information and integrate this with experience and observation to produce meaningful insights and actions (Evans et al., 2017; Wolfert et al., 2017).

2.4.2.2 Data Quality and Quantity

For data to help improve decision making, they need to be of high quality (i.e. reliable, relevant), and collected and available in a timely manner (Fountas et al., 2015). That is, they need to meet FAIR (findable, accessible, interoperable and reusable) data standards (Wilkinson et al., 2016). Heterogeneity in on-farm data is often inferred by statements about the range of methods and formats by which data are collected and held. Although digitisation of data storage and digitalisation of data collection can each increase the quantity of data, they can still result in poor data quality if methods of validation are lacking (Skinner et al., 2017; Wolfert et al., 2017).

Digital systems in agriculture are often data rich but information poor (Wolfert et al., 2017). The poor quality of some data can be offset by the quantity produced by automated data acquisition systems, especially when a larger data quantity—for example, more data points from an area collected during the same operation/time frame— increases resolution; however attention to calibration to improve data quality is preferred (Skinner et al., 2017). The quantity of data generated by PA has been shown to exceed the time and ability of farm managers to analyse and use the data to improve management (Zhang et al., 2017). Consequently, the quality of data is valued over the quantity, even in analogue formats. Quality data support the evolution to systems of more automated data collection, storage and analysis (Jakku et al., 2019; Newton et al., 2020; Wolfert et al., 2017).

Lack of quality data is not only an issue for farming businesses and the digitalisation of their on-farm process but is a significant obstacle to digital businesses trying to develop a market. Without quality data, potential purchasers of digital solutions lack confidence in the solutions as they may have only been tested on small datasets (Barry et al., 2017; Jakku et al., 2019). Some of the national datasets—for example those for soil or weather—lack sufficient spatial resolution across the landscape, and even for datasets with sufficient resolution, commercial access can be limited by governments or their host institutions, stymieing the development of new DSTs (Bahlo et al., 2019; Wolfert et al., 2017).

2.4.2.3 Data Interoperability

Access to quality data is one issue; the format in which it is held is another. The requirement for standardised data formats for the agri-food sector to enable data exchange for commercial and public good outcomes has been discussed widely (Bahlo et al., 2019; Fountas et al., 2015; Janssen et al., 2017). Open data standards and common data languages enable data collected on different platforms to be interoperable and transferable, and to help agriculture realise digital transformation (Bahlo et al., 2019; Evans et al., 2017; Fountas et al., 2015; Jakku et al., 2019). The creation of standard approaches within a technology's application programming interface (API) enables devices, apps and data to be interconnected over the internet, offering vast opportunities for remote management beyond simple observation (Evans et al., 2017; Wang et al., 2020). While data remains in silos, the development of on farm, and data flows along the value chain will be limited.

2.4.2.4 Ownership and Trust

With traditional analogue datasets and on-farm data storage, farm businesses retain control of their data. Digital tools—sensors, apps, software and so on—come with software and data ownership agreements because data are seen as a valuable commodity, prized by data scientists and commercial suppliers of digital solutions (Bronson, 2019; Jakku et al., 2019). With lack of regulation, data ownership favours suppliers of software and digital services, leaving some farming businesses concerned over data privacy, security, issues of ethics and misuse of their data, and even loss of control of their farm (Bacco et al.,2019; Jakku et al., 2019). Manufactures argue that sensors gathering data on machine functionality, performance and error diagnostics benefit farming businesses. There is concern that these and similar data agreements also encompass owner consent for the collection and use of commercially valuable data, beyond the remit of machinery efficiency monitoring (Relf-Eckstein et al., 2019; Wiseman & Sanderson, 2017).

There is a range of opinions regarding data privacy and security. Some farmers have expressed concern; others considered privacy and security measures to be adequate, while others admitted to having little knowledge of the details of the data collection agreements they have with service providers (Wiseman & Sanderson, 2017; Zhang et al., 2017). There have been calls for improved and more transparent provisions for the protection of agricultural data and the need for specific legislation to build farmer confidence to digitise data and digitalise processes (Bacco et al., 2019; Wiseman & Sanderson, 2017). Until such transparency exists, confidence in the use of digital solutions will be curbed and the predicted value proposition of digital transformation supported by institutions and commercial organisation (Perrett et al., 2017) will be difficult to achieve. Data codes of practice or similar types of structure have been created in the USA, New Zealand and, more recently, the EU and Australia (Burg et al., 2020; National Farmers Federation, 2020; Wiseman & Sanderson, 2017).

2.4.3 Summary of Section 2.4

The key differentiation between precision and digitalised systems is that the latter require network connectivity and interoperable datasets. Three levels of connectivity currently exist, with availability determined by institutional factors and use by on-farm desire. Lack of knowledge and support are considered barriers to implementing on-farm connectivity solutions.

Data are at the heart of DA; if farmers are to engage and capitalise on DA, a culture of collecting, analysing and using digital data in their decision making must be developed. Issues of data quality, and data flows through a process and ultimately a value chain need to be understood and addressed by those creating analytical systems required for data interpretation and data driven decision making. Failure to address these issues and those of user concerns regarding data tenure will continue to make it difficult for developers and users to see value propositions from digital approaches. Without the required foundation datasets in a common data language and interoperable format, digital systems will remain disparate, digitalised processes limited, and agricultural use of big data ad hoc and immature.

2.5 Supporting On-farm Digital Change

Making changes, especially to a productive system, can be risky: a farming business needs a good reason to adopt new technologies. An understanding of the factors that promote change and how family farming business make decisions are required if methods to support change are to be delivered.

2.5.1 Why Change?

Increased profitability is often assumed to be the main reason for adoption (Kutter et al., 2011; Tey & Brindal, 2012). Indeed, improved financial performance is regularly reported by farmers as a key driver for adoption of digital technology (Bramley & Ouzman, 2019; Chetty et al., 2018). This is potentially a reflection of research and marketing that demonstrates improved financial outcomes from the use of digital technologies (Kernecker et al., 2020; Perrett et al., 2017). If it were that simple, then once improved profit because of the use of digital technology was identified, adoption would automatically follow. This is rarely true because digital changes are generally complex, and personal values influence family business decisions (Kaine et al., 2011).

Vanclay (2011, p. 53) stated ‘Profit is not the main driving force of family farming businesses’. That means family farming business will, and do, change, but the change needs to be on their own terms. Consequently, their purchasing decisions can seem irrational and appear to prioritise personal needs over business logic (Long, 2013; Lundström, 2016). This is because the value proposition for individuals and for the family business is influenced by the perceived attributes of the technology and by the innovativeness of the business team members (Rogers, 2003). Applying their household adoption of technology model (a modified version of TAM) to the adoption of high speed broadband in Australia, Adams et al. (2017) identified four belief structures key to explaining variance in behavioural intention to subscribe to high-speed broadband. These were, in order of decreasing importance: lifestyle compatibility; perceived affordability; purchase complexity (that the researchers had anticipated to be negative but was in fact positive); and social influence. Adoption research in agriculture has reported that change is more likely to occur when there are clear value propositions that align with the personal goals of those in the business and the family (Fulton & Vanclay, 2011). Achieving change to digital requires approaches that enable the individualist nature of family farming businesses to be expressed; and end-to-end systems that are fit for purpose and time.

History shows that some innovations occur before their time and require a secondary innovation, or ‘killer app’, to trigger adoption. For example, the first tractor with a combustion engine was launched in 1902, but it took the invention of the pneumatic tyre in 1932 enabling tractors to travel on roads for them to become common place on farms in the USA (Lowenberg-DeBoer & Erickson, 2019). Thus, it can be difficult to disentangle the forces at play in the adoption of complex solutions (Kuehne et al., 2017; Miller et al., 2018). Research findings by Kuehne et al. (2017) in

Australia concur (Table 2.4), in that simple technologies are taken up more rapidly than complex changes to a system, providing there is a strong value proposition.

Overestimation of the population of possible adopters often occurs (Kaine et al., 2011), which can result in commercial disillusionment with the market (AgFunder, 2020). This has been experienced with PA with lower-than-anticipated rates of adoption for some technologies and sectors (Bacco et al., 2019; Bramley & Ouzman, 2019; Lowenberg-DeBoer & Erickson, 2019). Experience with PA adoption suggests that the proposition to change to DA should be considered in terms of the size and the value of the adoption step (Yule & Wood).

Table 2.4

Time to Peak Adoption Ranked by Complexity (Kuehne et al., 2017)

	Practice	Actual peak adoption (%)	Time to actual peak adoption (years)
Simple	Mace wheat (WA)	67	6
	Bt cotton	90	9
	Lupins (WA)	75	10
	Autosteer	83	20
Complex	No-till seeding (SA)	83	22

Note. SA, South Australia; WA, Western Australia.

Digital adoption can require a change of mindset (Eastwood et al., 2019; Jansen et al., 2012). In order to assist farmers to change they researchers, developers, extension services and trusted advisers all need to understand a farm business' motivations to adopt or avoid digital solutions. Three factors have been found to influence data appreciation by Australian grain producers: greater knowledge of telecommunication options, number of data types collected, and availability of technical support for DA (Zhang et al., 2017). As the use of data is at the heart of DA, a culture of collecting quality digital data and its analysis and use in decision making needs to be developed if DA adoption is to flourish.

2.5.2 How Farmers Make Decisions, Learn and Change

Decisions made by farmers and their advisers can be divided into three categories: 1) simple; 2) complicated; and 3) complex, with the number of potential variables, solutions and requirement for analysis increasing sequentially (Evans et al., 2017). In turn, Evans and colleagues identified five basic steps to generate information from data, termed: 1) discover; 2) communicate; 3) ingest; 4) analyse; and 5) expose. While these steps are recognised within farming business decision making and the execution of tasks and workflows (Evans et al., 2017), they are unlikely to be clearly articulated and recorded. As a result, on-farm decision making can appear to lack structure and logic, often being guided by personal rather than profit-driven goals and lacking consideration of connected process than can be delivered by digital solutions (Long, 2013; Lundström, 2016; Vanclay, 2011). This lack of logic in adoption decisions made by the family farming business has been explained by the low level of tertiary education among male famers (Kilpatrick & Johns, 2003; Zhang et al., 2017) and their use of intuitive decision- making processes (Long, 2013).

Lack of formal education aligns with farmers' reliance on experiential rather than experimental learning (Eastwood et al., 2017; Long, 2013), and that their decisions are strongly influenced by other farmers and advisers such as agronomists, veterinarians, resellers of inputs and networks of these individuals (Kilpatrick & Johns, 2003; Llewellyn, 2014; Long, 2013). In their research, Kilpatrick and Johns (2003) found a farming business would rely on a few influencers local to the business or a vast number contacted through extensive networks. Those with wider networks were more likely to make strategic changes such as starting a new enterprise or buying land. This socially embedded learning process is common in small businesses and an especially important feature of the decision-to-change process (Kilpatrick & Johns, 2003).

Education and training, together with farm profitability, have been strongly linked to the ability to successfully make changes to farm management practices (Kilpatrick, 2000). Farming businesses lack a culture of education and lifelong learning through formal, accredited systems. Issues including cost, time, location, childcare and lack of confidence as learners have all been cited as barriers to farmers' uptake of formal education and training (Kilpatrick & Johns, 2003). However, less formal, more practical extension and education programs are used to change mindsets in agriculture. To gain traction and achieve adoption, such programs need to target the 'right people at the right time' (Fulton & Vanclay, 2011, p. 128), and that might not just be the farmer. A study of females involved with farm businesses highlighted their superior computer skills, compared to male managers of a similar age and that in these Queensland based pastoral businesses women were driving digital adoption (Hay & Pearce, 2014). Similarly, the role of young family members who have greater natural aptitude for digital technology, is vital (Zhang et al., 2017) The 'right time' is yet again going to be driven by the individual business.

It has been suggested that the slow rate of adoption of PA is because of the use of traditional linear extension models (Yule & Wood). Such models tend to be top down, rather than bottom up. Turning extension models upside down allows peer-to-peer learning, where members of a farming business construct their own knowledge, relevant to their needs and wants (Eastwood et al., 2017; Kilpatrick & Johns, 2003; Long, 2013). Ideally, peer groups need a range of levels of experience, knowledge and skills, and the ability and tools to communicate these to the other members of the group.

2.5.3 Change Management

Implementing adoption, the stage after the decision to adopt, is the fourth of the five stages of Rogers's (2003) innovation decision (Figure 2.4). While diffusion of innovation theory provides a guiding framework for the process of adoption, it does not provide guidance on how to achieve successful implementation. Practice change and implementation of technology adoption fall within the bounds of change management theory. Many models have been designed to guide the transition of people, projects and organisations from one situation to another. These vary in complexity, structure and focus. Common features are that successful change management requires a strong reason to change, whole-team engagement, leadership, planning and a method to measure progress (Hiatt, 2006). Understanding the current position and desired result from a change is fundamental to this approach.

Kurt Lewin is recognised as the initiator of change management theory and action research (Cummings et al., 2016). His model, developed in the late 1940s, provides a clear approach for change in a specific area of an entity whereby a business process is thawed, changed and then re-frozen (Cummings et al., 2016). While still supported by many, others consider the approach too autocratic (Axelsen, 2007). Today, the thaw–change–freeze approach is aligned with business process reengineering, a subset of change management that supports operational change in one facet of a business (Axelsen, 2007). The focus is changing the practice or process, rather than supporting the people who implement the process change.

An eight-stage change management process designed by John Kotter became popular in the late 20th century. This more complex process is suited to businesses with clear hierarchical management structure centres, using top-down guidance to drive organisational change (Kotter, 1996). The eight stages are based around 1) a sense of urgency for change; 2) a guiding coalition of leaders; 3) strategic vision and initiatives; 4) a volunteer army; 5) removal of barriers to achieving change; 6) generating short-term wins; 7) sustaining acceleration; and 8) instituting the change (Kotter, 1996). Such language and top-down approach are unsuited to family farming business that have flat management structures and small teams.

A simple model to deliver individual change is ADKAR, developed by Jeff Hiatt, founder of Prosci (Hiatt, 2006). The word ADKAR is an acronym (awareness, desire, knowledge, ability and reinforcement) of the five areas that need to be achieved by individual for successful change to be achieved. The ADKAR process employs a behavioural, rather than an organisational change approach. By paying attention to an individual's values and desires, the change process builds knowledge and ability to achieve successful change to meet business goals. ADKAR is a stepwise model that starts after the decision to change has been made. The five steps of the ADKAR model for individual behavioural change are closely aligned with the five stages in the innovation decision outlined by Rogers (2003) (Figure 2.4). Because of the focus on the individual, the ADKAR approach is relevant for small and large organisations with flat and hierarchical management structures. Therefore, ADKAR is considered a suitable model for use with family farming businesses.

The RESET (regulations, education, social pressure, economic incentives and tools) farmer mindset model is based on the theory of planned behaviour to achieve behavioural change, including a change in mindset (Jansen et al., 2012). It recognises that behaviour can change either voluntarily or because of coercion and regulation, with some people motivated by negative stimuli and some by positive. The model shows five main instruments, represented by the acronym, that need to be addressed when a change in behaviour of people is required. It has been applied in the development of extension models to deliver on-farm change, rather than for farming businesses to develop their own change strategy. RESET is a top down rather than bottom-up model designed to drive rather than support change; hence it was not the model of choice for this research.

The Digital Value Assessment Tool has been developed collaboratively with farm advisers and is designed to help advisers work through nine considerations when adopting a digital technology (Ayre et al., 2019). The nine considerations are 1) technology; 2) financial; 3) people; 4) research and development; 5) legal; 6) support; 7) market; 8) environmental; and 9) social. Further details of the tool and its implementation are yet to be released and could not be sourced for use.

2.5.4 Summary of Section 2.5

Change takes time, and the experience of other on-farm technology adoption shows farming business will change when the innovation meets their goals. Financial benefits are often promoted as a key driver to change but in family farming businesses the aspirations, attitude and ability of the individuals in the team all influence the change decision. The bottom line for on-farm digital transformation is that one size does not fit all in terms of when, what and how to adopt. Consequently, bottom-up approaches driven by the farming business rather than top-down programs delivered via third parties are considered more appropriate to support farming businesses to clarify their digital value propositions.

However, extension programs are a key method for conveying new knowledge to farming businesses but need to offer flexible systems that embrace the whole farming team. The ADKAR change management model provides a practical framework to help guide the *people* part of change. As it pays attention to individuals' needs and using clear language, this change management approach was considered the most appropriate to use with family farming businesses. The five steps of the model can be aligned with the five stages in the innovation decision to align the change needs of the people and the business.

2.6 The Case for this Research to be Undertaken

Agriculture is recognised as one of the least digitalised industry sectors globally, and governments see the opportunity for digital solutions to secure productivity and markets, and deliver sustainability solutions along a digitally connected supply chain. The issues promoting and limiting digital adoption by family farming businesses, which dominate in Australia, were presented in this literature review.

The complexity of digitalisation, the unique scenario presented by every family farming business and the apparent lack of logic behind decisions made by these businesses have been widely acknowledged in the literature reviewed. Despite connectivity and data solutions evolving rapidly, farming businesses often lack confidence, skills, knowledge, adoption support and a clear understanding of the value proposition offered by digital change to their business. All these factors are recognised as presenting barriers to adoption of digital technologies and approaches.

Adoption theory illustrates the factors that influence technology adoption, and change management theory offers a practical way to guide complex on-farm change to meet the goals of individual farming businesses. Based on the need to develop flexible, digital change specific to family farming businesses, approaches that are driven from the bottom up are most suited. Such systems need to help a farming business define and achieve goals by using digitalised processes; this will be the digital value proposition for that farming business. Defining the value proposition for digital change has been found to be lacking from a user's perspective and needs to be user specific.

The review did not identify a supporting framework specifically designed to provide a practical guide for on-farm adoption of digital solutions, but did identify frameworks that could be modified. Information on how suppliers of digital hardware, software and digital services to farming business perceive and address barriers to adoption of their solutions was found to be lacking in the academic literature. The following research questions have been designed to address these gaps in the literature, with the aim of producing an outcome of practical use for farming businesses and businesses involved in the wider agricultural value chain.

The overarching gaps in the literature that will be addressed by the research question and sub-questions are:

- a lack of appropriate guiding frameworks designed for on-farm digital agricultural adoption
- minimal understanding of commercial providers' points of view on the barriers to DA adoption.

2.7 Research Questions

A mixed methods approach, dominated by qualitative research methods was used to address the main research question (RQM);

RQM: *How can an adoption framework improve uptake and use of digital agriculture by a family farming business?*

The following sub-questions were posed to help gain a deeper understanding of the issues that influence DA adoption:

RQ1: *What are the fundamental components of digital agriculture for grain, livestock and mixed farming businesses?*

RQ2: *Why and how do farm businesses initiate the use of digital technologies for farm management and how could this be supported by a change management approach?*

RQ3: *How do commercial providers of digital agricultural hardware, software or support services view and address the barriers to uptake of digital agriculture?*

2.8 Summary of Chapter 2

The evolution from manual and analogue tasks to digital processes is complex and consists of three central elements: 1) digitisation of data; 2) digitalisation of processes; and 3) transformation to new business models and production systems, as illustrated in Figure 2.1 (Savic, 2019). While data and connectivity are common threads in these three elements, the technologies required for process and system implementation are numerous: one size does not fit all. Consequently, complex changes can be achieved from multiple combinations of technology bundles (Evans et al., 2017). Users are motivated to adopt technology they find easy to use and useful and that provide a value proposition.

Adoption takes time, with more complex technologies with less obvious value propositions being the slowest to gain market share. A lack of clearly articulated value propositions is suffered by farming industries. This may be why agriculture is reported as one of the least digitally transformed industry sectors. Six barriers to digital adoption have been identified (Leonard et al., 2017):

- lack of value propositions
- low digital skills
- issues with connectivity
- the type and quality of available data
- data formats and potential for integration and analysis
- trust and legal issues around data use and ownership.

Many digital solutions are immature and not always fit for purpose because of a disconnect between developers and users. To support on-farm digital change, approaches need to bring together all members of the family, farm and support team of the business to capitalise on skills and knowledge. The support process needs to be able to help meet the individual goals of each family farming business in relation to digital change. Existing change management and adoption models provide a framework that can be modified and populated to meet the specific needs of on-farm digital change. The development of such modified models was addressed in this research. In Chapter 3, methodology is explored to establish the most appropriate approach and methods to address the research questions.

Chapter 3: Methodology

This chapter describes the methodology underpinning this research, laying out the arguments for the choice of research paradigm, perspective and approach. All research demands careful planning with consideration to accessing data in a low-risk, timely, ethical and cost-effective manner. In addition, approaches that provide reliable sources and that can be evaluated and rigorously interpreted are required.

The literature on research philosophy and implementation frameworks describes an array of approaches using language that can be confusing, especially for the novice researcher. This is especially true when multiple terms have the same meaning; for example, qualitative research may also be referred to as naturalistic or interpretive research. Exacerbating this problem, the same term can be ascribed different meanings by different researchers. The latter point is clearly illustrated where Yin (1994) describes 'trustworthiness as a criterion to test the quality of research design, while Guba and Lincoln (1989) refer to it as a goal of the research' (as cited in Morse et al., 2002, p. 16).

Similarly, the literature presents varied grouping and naming of even the most fundamental aspects of methodology—the interpretive paradigms that underpin qualitative research. Denzin and Lincoln (2011) proposed four major paradigms: 1) positivist/post-positivist; 2) constructivist–interpretivist; 3) critical (Marxist, emancipatory); and 4) feminist–post-structuralist. While Creswell (2009) concurred with the first two, they identified other paradigms as advocacy or participatory, and *pragmatic* (for issues of application and use). A third view was proposed by Mertens and Tarsilla (2015), who termed the third paradigm transformative, dealing with issues of social justice.

To help the reader navigate these different schools of methodological thought, this chapter is structured around the five aspects of the qualitative research process as laid out Creswell (2006) and promoted by Denzin and Lincoln (2011):

1. the influence of the researcher
2. theoretical paradigms and perspectives
3. research strategies
4. data collection and analysis
5. interpretation and evaluation.

The methodology selected for this research is a constructivist paradigm implementing a mixed methods approach, dominated by qualitative data evaluation. Consequently, discussion regarding choice of research strategy and subsequent data collection, analysis and interpretation methods are confined to those appropriate to this methodology. The arguments for the choices made are focussed on the need to address the perceptions of farming businesses and their advisers regarding the value of an adoption framework to support decisions regarding how, why and when to adopt DA on farm, to address RQM: *How can an adoption framework improve uptake and use of digital agriculture by a family farming business?* And to address the sub questions R1, R2 and R3 (see section 2.7)

3.1 The Influence of the Researcher

To research is to seek new knowledge or establish a new perspective initiated by the questions posed by the researcher or team. However, each researcher is influenced by their own philosophy, culture, ideas, knowledge, experience and beliefs, which will be reflected when asking and answering research questions (Creswell, 2006). The degree to which a researcher becomes embedded depends on the theoretical paradigm implemented. Where the research is quantitative, using deductive methods of surveying or experimentation, the researcher needs to remain objective and detached from the data generation. Conversely, qualitative research generally locates the researcher in the field to build relationships with participants, and confront the ethics and politics of their own research (Denzin & Lincoln, 2011).

This embedded nature of the qualitative researcher requires their history be exposed and their biases recognised. The researcher's perspective on the investigation is termed 'their lens' and this will have subjective and objective qualities (Yin, 2010). By reflecting on their personal background and experience, the qualitative researcher's biases and values that they bring to the research are exposed (Creswell, 2009). Consequently, the researcher's personal experience, knowledge and ambitions will influence interactions with, and interpretations of, the data. With over 25 years of work in agricultural technology transfer, this researcher understands they begin this work with beliefs and experiences that need to be clarified at the outset.

3.2 Theoretical Paradigms and Perspectives

The metaphor of a tree is a useful way to simplify the relationships between and evolution of research paradigms and perspectives (Gupta & Awasthy, 2015). Starting with the trunk, Gupta and Awasthy (2015) proposed this represents the origins of research—the physical sciences, which are based in positivism and objective, quantifiable research. Positivism is for those that see the world as black and white; they explore to find answers, rather than meanings. As the trunk divides into major branches, this area of the tree represents neo- or post-positivism, where the ability to produce definitive understanding is affected by a lack of absolutes and increasing number of variables (Creswell, 2006). Research following a positivist or post-positivist paradigm establishes a hypothesis that is tested with randomised controlled experiments to quantify differences between variables. Post-positivism acknowledges that science can require broader empirical approaches including observation to substantiate facts (Gupta & Awasthy, 2015). Research using a post-positivist paradigm is objective, aiming to class and count phenomena and use statistical modelling to explain these observations (Creswell, 2009).

The tree's canopy represents the interpretivist paradigm with its many branches of the social sciences. In contrast to the post-positivist search for definitive, empirical results, interpretivism searches for understanding of the social world and embraces difference and diversity. It takes a holistic approach to exploring a question, which can demand multiple research approaches are employed. Research that seeks to interpret and understand dynamic situations is subjective and qualitative in nature (Creswell, 2009; Denzin & Lincoln, 2011; Hesse-Biber et al., 2015). Rather than numbers, words and in some instances images and artefacts, are the currency for analysis in qualitative research. This analysis often takes multiple forms and the same dataset may be analysed many times from different perspectives; a term Gupta and Awasthy (2015) referred to as 'data churning'.

Interpretivism places the participant's individual perspective on the reality of the issue in question at the centre of the research but recognises this can change with time. This evolution of the opinions and experiences of participant and researcher is captured by using reflective practices and the embedding of the researcher within the research, rather than as an external actor. The interpretivist paradigm embraces many perspectives including critical theory, feminism, cultural studies and racialised discourse; indeed qualitative research is about theory creation, rather than theory testing (Gupta & Awasthy, 2015). Interpretivism embraces the more subjective, qualitative social sciences that have flourished in the 20th century. The interpretivist paradigm contains many perspectives or *worldviews*—the term preferred by Creswell (2009)—including constructivism (interpreting values) and pragmatism (based in application) (Mertens & Tarsilla, 2015).

Interpretivist research is conducted in reverse to a post-positivist approach, evolving from the bottom up; from the raw data to themes, descriptions and theories (Creswell, 2009). Many of these theories originate from the foundation that knowledge is established through social construction of the world in which we live (Creswell, 2006). Researchers implementing a social constructivist approach argue that knowledge construction helps people improve themselves and their community, which is achieved by shared experiences (Creswell, 2006). To seek understanding, individuals interpret their own situations and ascribe meanings to objects and experiences. The researcher seeks to expand and decipher these meanings for a community by combining the experiences of multiple individuals (Creswell, 2009). Research questions are designed to be broad. This enables participants to interact and respond without constraint and for researchers to use systematic enquiry to unwrap experiences, which they interpret in relation to the situation (Mertens & Tarsilla, 2015).

In contrast, research with a pragmatic perspective is outcome focussed; it assesses situations, actions and consequences. The main concern is finding what works and solutions to problems (Creswell, 2006). The focus of pragmatic research is evaluation but not in a post-positivist, one-dimensional, detached approach; rather it occurs through the observations and experiences of a researcher who is embedded in an environment reflecting on multiple issues: 'In order to take intelligent action, evaluators need to interact with the communities with which they work and be open to critical reflection' (Mertens & Tarsilla, 2015, p. 437).

Unlike the other paradigms, pragmatism is not confined to a single research strategy or method of data collection, analysis, interpretation or evaluation. Indeed, evaluation of real-world experience and their consequences is central to pragmatic research (Mertens & Tarsilla, 2015). This freer approach to the research philosophy that evolves to respond to issues emanating from the findings results in the use of a mixture of qualitative and quantitative approaches, termed mixed methods.

3.2.1 Mixed Methods

Not all research questions can be addressed using a single paradigm. Some require multiple qualitative or quantitative methods. Hesse-Biber et al. (2015) identified that all research is on a continuum, with mixed methods research led by either a qualitative or quantitative standpoint, and the secondary method employed to answer sub-questions, provide clarification and triangulate data. The use of a mixed methods approach aims to capitalise on the similarities and differences of worldviews associated with qualitative or quantitative perspectives, without the need to resolve conflicts between them (Yin, 2010).

The use of mixed methods approaches creates new challenges for the researcher, requiring familiarity with both quantitative and qualitative approaches at all stages of the research (Hesse-Biber et al., 2015). It can also be more demanding on time, especially if discrepancies between data types need to be resolved (Creswell, 2009).

Common applications of mixed methods approaches are the use of quantitative methods to test, gain new perspectives and verify ideas produced from the collection of qualitative data (Mertens & Tarsilla, 2015). This combination of methods may also be applied to help define a population of interest and obtain a representative subsample. Equally, a research project may be dominated by a quantitative method but include a qualitative approach to better understand the social influences on a phenomenon. For example, a study on the effects of smoking may quantify the health issues of the sample, but a subjective study of individuals may highlight motivations for smoking and factors that would support practice change. The use of both approaches provides a broader perspective to the research.

There are four key components of a mixed methods design that should be described and implemented—timing, weighting, mixing and the theorising perspective (Creswell, 2009):

- Timing refers to whether the methods are used sequentially or concurrently. While mixed methods approaches can be time consuming, some approaches enable qualitative and quantitative data to be collected concurrently, in one data collection phase.
- Weighting identifies which is the dominant and which is the secondary approach. The dominant approach is indicated using capitals (QUAL) and the secondary, all lower case (qant).
- Mixing implies how data collection and analysis are handled where data from the two elements of the research may be integrated, connected or embedded. Mixed methods designs often have the secondary method nested, or embedded within the dominant method, to support reflection on the outcomes from the dominant method (Mertens & Tarsilla, 2015).
- The selection of the predominant theorising perspective that links the two parts of the research may be implied, as in sequential, quantitative dominant and embedded research. In concurrent research, with equal weight given to each part, and an integrated design, explanation of the predominant theory is required (Creswell, 2009). The other combinations of designs sit between explicit and implicit, and some perspective on the predominant theory is required to provide the reader with sufficient understanding of the effects of the researcher’s lens on the outcomes (Yin, 2010).

3.3 Research Strategies

The research strategy provides the framework for how the research will be conducted. Once the research paradigm is identified and the theoretical perspective selected, the field of potential research strategies is narrowed. Strategy selection is also entwined with issues of sample size, data collection methods and research ethics (Gupta & Awasthy, 2015). Research strategies suited to qualitative research include case study (situation observation at a current point in time), ethnography (participant observation at a current point in time), grounded theory (naturalistic theory building), ethnography and phenomenology (analytical description of social groups or phenomena), narrative inquiry (the study of experience as a story) and action research (participants drive the research, in their own environment) (Creswell, 2006; Gupta & Awasthy, 2015; Kemmis et al., 2013). In the post-positivist, scientific disciplines, quantitative research uses experimental strategies containing replicated trials, with empirical surveying approaches providing a primary or supporting quantitative strategy (Creswell, 2009). Experimental designs vary to delivery exploratory or conclusive evidence. However, strategies based around objective, empirical data collection and validation through statistical analysis are also employed in many spheres of the social sciences that study social development, including economics, project management, health science and education. Quantitative strategies used in the social sciences are often descriptive, rather than experimental with subjects measured once, or before and after a treatment (Hesse-Biber et al., 2015). Such strategies include cost–benefit analysis, welfare economics, social auditing and game theory (Singh, 2007). A mixed methods strategy provides the opportunity for descriptive and reflective research strategies, supported by empirical approaches to reinforce and justify qualitative observations (Morse, 2015).

Choice of qualitative research strategy is influenced by the motivations and objectives of the research as well as more practical issues including the time frame of data collection (e.g., current, historical, future or evolving); the degree to which the researcher is embedded in and influences the research environment; and the phenomenon of interest (Gupta & Awasthy, 2015). As stated at the beginning of the chapter, the choice of research strategy and subsequent data collection, analysis and interpretation methods are confined to those appropriate to the qualitatively dominated, mixed methods approach selected as the most suited to RQM: *How can an adoption framework improve uptake and use of digital agriculture by a family farming business?* As this question relates to supporting change, an action research approach is considered the most relevant qualitative strategy. Surveys and evaluation approaches provide objective reinforcement to support answering the main and sub-questions.

3.3.1 Action Research

Action research takes interpretivism to the next level by using understanding of the phenomenon to support a population in their environment to make improvements to their situation (Kemmis et al., 2013). It engages communities to contribute to and collaborate with the research rather than purely be its focus. This approach contrasts with passive research strategies that require participants to only comply and cooperate. Action research is especially valued in business and education environments, including in agricultural extension, especially through local and regional user groups. Kemmis et al. (2013) described seven types of action research, of which industrial action research, action science and action learning are three subsets that focus on organisational/business settings. Another form of action research uses a soft systems approach, with the soft system referring to the human system of managers and workers, in contrast to hard systems which refer to industrial production. Participatory classroom action and critical participatory action research (PAR) are strongly associated with educational research, with participatory research especially associated with community research in rural and developing countries. In Australia, the system of paying levies on production to support research, development and extension results in farmers having a strong awareness and often engagement with on-farm research (Department of Agriculture Water and the Environment, 2021).

PAR encourages participants to be involved in all stages of the research process. Such participatory involvement in research was initiated by Kurt Lewin and published in 1947 as a three-step change process: thaw–change–refreeze (Cummings et al., 2016). Lewin maintained that the researcher is a facilitator of the research, an approach criticised by some because of the influence of self-interest of the researcher conflicting with that of the participants (Kemmis et al., 2013). Nevertheless, Lewin's approach provides the foundation for PAR; in particular, industrial action research and action science. Both of these action approaches employ stepwise change, guided by an internal or external member of the social system who works with participants in their environment, to identify issues and then engage with, understand and implement the change, using the reflective practices of plan, act, observe, reflect and re-plan (Kemmis et al., 2013).

PAR can be time and resource extensive and places specific challenges on the researcher requiring excellent organisation and communication skills (Mackenzie et al., 2012). This can result in the research becoming more of a facilitator than academic. Due to the interpersonal nature of PAR repeatability of results can be an issue.

3.3.2 Sampling

The choice of research participants, sample size and research setting are driven by the research hypothesis or question, and differ according to the research approach. Quantitative research aims to work with a sample that is as representative of the population of interest as feasible; this is achieved by random selection processes. The sample size is often large but defined based on the total population and the hypothesis or research question. The sampling process may consist of a single or multiple stages, and the population might be stratified into sectors (Creswell, 2009). Outcomes from quantitative research are usually generalised to the population, in contrast to qualitative research where outcomes are generalised to the situation (Yin, 2010).

The sample for qualitative research is rarely a representative population (Schreier, 2018b), and data collection is often initiated without deciding on a total sample size required: 'data collection occurs until the researcher reaches theoretical saturation' (Basu, 2015, p. 77). The selection of participants will be guided by the research question and the literature. Selection will focus on participants that can provide the most pertinent, complete and detailed information, and a sample can even consist of a single case (Gupta & Awasthy, 2015). Detailed description of the logic behind these choices is required to inform the reader of the context and logic for the sample selection.

On the surface, qualitative analysis has a less structured and freer approach to sample selection and size, but conventions and points of reference do offer guidance. Schreier (2018b) encouraged consideration of how the research may be generalised and how the findings will apply within and beyond the period of research. For qualitative research, she proposed three choices of sampling strategy; random, purposive and convenience, which decrease in level of objectiveness and structure from random to convenience. Purposive sampling provides some of the rigour of random sampling, and the facility of convenience sampling is appropriate in both theory testing and research designed to be transferable to a wider population. The purposive sample can be targeted to meet specific criteria required to address the research question, and the population can be diverse or homogenous, described by the relationships between the choice of sample units.

Qualitative research aims to continue sampling and collecting data until saturation is achieved—an ideal that can be difficult to align with the criteria required in applications to funding bodies and ethics committees. Indeed, identifying saturation is a point of much contention in the qualitative literature (Schreier, 2018b). The current research is guided by the requirement for data repetition, from a minimum of 3 participants, with themes emerging with 6 and saturation achieved with 12 participants (Guest et al. 2006, Francis et al. 2010 as cited in Schreier, 2018b).

3.4 Data Collection and Analysis

New research knowledge is created from the analysis and interpretation of data, so ensuring the appropriateness of the sample and the way in which data are gathered, recorded and stored underpins rigorous research (Morse et al., 2002). More than one form of data collection may be used, (multiple methods), and this will always be the case in mixed methods approaches (Hesse-Biber et al., 2015). Quantitative data collection is confined to experimentation and the use of structured empirical data collection, including surveys, polls, questionnaires, financial reports and evaluation tools, in line with the research strategy selected. For qualitative research, Creswell (2009) proposed four primary methods of data collection, with each offering benefits and limitations: 1) observation; 2) interviews; 3) documents; and 4) audio-visual materials. Where surveys use open questions, subjective data are gathered, which can be considered a form of interview, although responses will differ because of constraints on space, time and literacy (Yin, 2010).

3.4.1 Qualitative Data Collection Instruments

In observational studies, the researcher may be embedded as a participant, either gaining first-hand experience or working purely as an observer in the field (Roy, 2015). In both situations, data can be gathered as field notes and reflection on occurrences. Developing rapport with participants and having a consistent level of observation are challenges experienced in this style of data collection, but it is suited to exploring topics that may be painful for participants to communicate in interviews (Mackenzie et al., 2012).

Data collection by interview can occur face to face in the field as well as by phone or video call, with individuals or groups. Using interview as the data collection instrument enables information to be recorded from a broader timeframe and provides researchers with tighter control over the data collection process and topics (Jenks, 2018). By using open, unstructured questions, the researcher can build rich descriptions about the participants' attitudes, experiences and expectations of a phenomenon (Creswell, 2009). However, interviewing requires good listening skills, and can result in hours of interviews needing to be transcribed and information that may be filtered by the prejudices and views of the researcher.

The use of documents as the primary source of data puts the researcher at the mercy of the original author in terms of accuracy and clarity but enables the voice of the participants to be captured (Jenks, 2018). Sourcing appropriate documentation may be difficult, although in the internet era, accessibility and availability has improved. Historic audio-visual sources offer similar benefits and limitations to those of documents or those created by the researcher during interviews or field observations. Audio-visual data collection methods enable greater context to be captured, but interpretation can be difficult (Creswell, 2009). New technology and advanced algorithms are offering new ways to collect and analyse audio-visual data.

This research used a combination of surveys and evaluation tools developed during the research to collect quantitative data and, for the collection of qualitative data, audio-visual interviews and video tutorials. Data collection, organisation and analysis was supported by digital research tools.

3.4.2 Surveys

In mixed methods research dominated by a qualitative approach, a survey or multiple surveys in a longitudinal design may be used to provide context to the qualitative data collection. Surveys offer the opportunity for participants to answer closed, structured questions and provide scaled descriptions of their perceptions. The responses from the sample population are used to make generalisations about the wider population and, in longitudinal studies, track change in the sample population overtime (Dolnicar, 2013; Fowler Jr. & Cosenza, 2009).

Software offers sophisticated methods for creating, distributing, collating and analysing survey data. As with all software, the data out are only as good as the data in, which is highly influenced by the reliability of survey design and use of appropriate approaches for scoring. Dolnicar (2013) explained that using multiple survey questions on the same issue is an important method to reduce misinterpretation of data because of survey errors. Careful construction of survey questions and scoring is vital to minimise sampling error (Fowler Jr. & Cosenza, 2009).

3.4.3 Data Reliability and Validity

Credible data need to be shown to be reliable (repeatable) and valid (measuring the intended phenomena). In quantitative research, reliability and validity are tested using statistical methods comparing treatments to controls, to test if the single view of reality is correct (Hesse-Biber et al., 2015). In qualitative research, reality is multiple; the terms reliability and validity carry different connotations.

Validity is achieved by applying multiple cross-checking procedures throughout the research process, while reliability relates to the consistent application of a research approach by following well-documented procedures (Creswell, 2009).

Qualitative validity is presented by cross-referencing the reality of findings from the perspective of the researcher, participant or reader of the account. The collection of multiple data sources from the same participants enables themes and the convergence or divergence of perspectives to be established (Creswell, 2009). When at least three different data sources are compared—referred to as data triangulation—a powerful validation technique is produced (Yin, 2010). The use of follow-up interviews and participant discussion groups to gain the subjects' perspectives on analysis and interpretation of data; and engaging in debriefing with peers or an external auditor are methods used to validate qualitative research. Other aspects of validation relate to illuminating researcher bias and spending prolonged time in the field to gain a broad and in-depth understanding of the phenomenon of interest in the environment in which it resides. Because of the iterative, rather than linear, nature of qualitative research, such validation techniques must be applied throughout the research. In this way, a self-correcting system is developed and research rigour improved (Morse et al., 2002).

Processes of data reliability in qualitative research relate to procedural consistency. The use of recognised practices for gathering data with specific collection methods such as interviewing, observation and visual methods supports reliability in qualitative data collection. Words are one of the currencies of qualitative research and textual analysis is a central mechanism for unlocking meaning in a dataset. Successful classification of text themes requires a systematic approach (Creswell, 2009; Schreier, 2018a). Termed qualitative content, thematic analysis or inductive coding, such practices are based around interpreting meaning from large texts by selection of phrases or words. Topics are ascribed categories, to create a code framework, while themes within in a topic are allocated codes. Each coding approach is defined by different requirements. For example in inductive coding, the framework can change during coding; whereas in qualitative content analysis this is fixed, so the research must define and explain the choice of coding system applied (Schreier, 2018a). Each category and code are described and recorded in a codebook to enable consistency of coding by individuals and multiple researchers working on the same text. While software can support interview transcription and coding, manual cross-checking is always required to ensure transcription mistakes and drifting from code definitions are corrected and avoided (Creswell, 2009). The production and sharing of a codebook are fundamental for reliable data analysis and interpretation.

3.4.4 Ethics and Data Storage

Data are research gold and need to be handled with care. Data often contain personal details and sensitive information. Consequently, at all stages of research, including the final storage and disposal of data, the researcher must treat their sources and the information received with the highest level of integrity and ethical consideration (Yin, 2010). Funding bodies, universities and governments will stipulate their requirements for data storage and treatment of ethical issues in internal codes of practice. Implementation of such codes provides participants with confidence regarding issues of confidentiality and anonymity.

For true reliability, data need to be stored in file formats and filing systems that can be extracted for further comparison or reuse in subsequent research. The use of recognised data management plans, nomenclature systems and metadata will all support future extraction and use of data for appropriate further research.

3.5 Interpretation and Evaluation

These final stages of a research project are vital. Interpretation of analysed data is where new knowledge and theories can be presented and where the need for further research and additional research questions are identified (Creswell, 2009). These needs are reiterated and summarised in the research conclusion.

Rigour in the interpretation phase is vital as the outputs will shape how the research is viewed by others. The term *interpretation* implies that others may view the data collection and analysis differently (Creswell, 2009). In turn, interpretation reflects the individual influences of the researcher, participants, initiators of the research and indeed the comprehension and bias of the reader (Cooksey, 2011; Denzin & Lincoln, 2011; Yin, 2010).

The evaluation stage offers the opportunity to discuss the success or failure of the chosen research approach in delivering rigorous research and is where situational issues that enhanced or impeded the chosen methods can be discussed, because as all seasoned researchers know, even the best-laid plans can go astray. Both these stages in qualitative and quantitative research provide the opportunity for the voice of the researcher to be heard, and are where all the preceding phases of research are drawn together (Denzin & Lincoln, 2011).

For quantitative research, this phase reports whether the experiment or survey proved or disproved the hypothesis, supported by discussion and explanations of the significance of the findings (Creswell, 2009). Quantitative research requires the completion of data collection before analysis and interpretation can occur. For qualitative research, interpretation generally involves returning to the data analysis phase and disassembling and reassembling data to clarify, revaluate and verify conclusions from the analysis (Yin, 2010).

In this way, the researcher is able to reflect and interpret findings as they occur, and evaluation can occur at multiple points or continuously through the study, as occurred in the current research.

Yin (2010) argued that rigorous qualitative research interpretation is supported by using an inductive approach to identify alignment of results with theories and other studies. This approach is based around one of three modes of interpretation: explanation; description; and description with a call for action. These three are not necessarily discrete; for example, explanation can form part of a descriptive interpretation. If consideration is given to the interpretation approach during research planning, this can support the most appropriate choice of research strategy.

As previously stated, reflection at all phases of qualitative research is vital and that remains true for the interpretation and evaluation phase. However, there is a point at which the researcher must stop because of limitations placed on the research and researcher. This does not prevent further analysis and interpretation of the data at a later stage and by other researchers. The potential reuse of qualitative data underlines the importance of rigour in both the selection of methodological framework and application of the research process.

3.6 Summary Chapter 3

This chapter has provided an overview of the five phases of the qualitative research process as laid out by Creswell (2006):

- the influence of the researcher
- theoretical paradigms and perspectives
- research strategies
- data collection and analysis
- interpretation and evaluation.

These have been used to introduce the process the researcher followed to develop the research design in this study, as presented in Chapter 4. The metaphor of the branching tree presented by Gupta and Awasthy (2015) illustrated the evolution of post-positivism to interpretivism research paradigms and the associated perspectives. From this description, the logic for the selection of a mixed methods approach based around social constructivism, implemented via a predominantly participatory action research approach based around soft systems, was laid out. To execute this mixed methods approach, a sequential research design with an embedded concurrent element was selected.

The research sample was a subset of Australian agriculture, with a focus on participants that can provide the most pertinent, complete and detailed information suited to the research question. The dominance of qualitative approaches in this mixed methods study permits a small sample size to be appropriate. The main research involved working with family farming businesses and the embedded research was with commercial providers to agriculture. The action research approach required a purposive sampling approach as the intention was to design research to be transferable to a wider population.

The qualitative data collection instruments were interview and audio-visual platforms, with the quantitative data collection instruments being survey and survey-type tools. Using multiple data collection approaches with the same population provides methods for data validation and triangulation and enables measurement of change over time. Qualitative analysis methods were intended to provide iterative thematic coding of interviews, with quantitative survey data used to contextualise findings and support the development of new data collection instruments. Descriptive statistics were used for qualitative data analysis.

Considerations were given to appropriate data analysis and ethical issues relating to evaluating, reporting and storing data. Full details of the implementation of this methodology are reported in Chapter 4.

Chapter 4: Method and Research Design

This chapter details how this research was executed and the logic behind each decision, enabling others to replicate this approach. The main research question addressed was: *'How can an adoption framework improve uptake and use of digital agriculture by a family farming business?'*

The research question was framed in relation to factors that might help promote future adoption, rather than measure the present situation. The thesis title, 'A Change Management Approach to Unlocking the Value of Digital Agriculture for Family Farming Businesses', identifies that the researcher is aware that value is difficult to access; however, the study did not aim to quantify value. Instead, the aim was to work with a small number of family farming businesses to develop an approach to help them identify and capture value from DA. It was acknowledged that further validation of the developed approach by a larger sample would be required.

To achieve this aim, the following sub-questions were posed to help gain a deeper understanding of the issues:

RQ1: *What are the fundamental components of digital agriculture for grain, livestock and mixed farming businesses?*

RQ2: *Why and how do farm businesses initiate the use of digital technologies for farm management and how could this be supported by a change management approach?*

The target audience for the research findings is family farming businesses, the dominant farming business structure in Australia. With small numbers of people, often running large and complex operations, family farming businesses frequently engage trusted advisers to introduce specialist skills and knowledge. The trusted adviser is a recognised influencer of technology adoption who interplays with the innovativeness of family farming members. Therefore, a team approach was used with each farming business. Teams consisted of at least one Manager and Operator from within the business and a Trusted Adviser from outside the business. With five farming teams, this involved a total of 18 participants.

Adoption is also influenced by the technology itself. To gain insights into the influence that current digital agricultural technologies might be having on adoption, a further sub-question was posed to an additional target audience of commercial providers of digital agricultural technology:

> RQ3: *How do commercial providers of digital agricultural hardware, software or support services view and address the barriers to uptake of digital agriculture?*

To address this research question, a mixed methods sequential design with an embedded concurrent element was implemented. The design was dominated by qualitative action research approaches. The embedded study addressed sub-question RQ3. All data collection occurred remotely, via three data collection instruments: surveys, semi-structured interviews and video tutorials. Data from Farm Business Teams (from here on referred to as teams) and the Commercial Providers (from here on referred to as providers) were layered to develop a rich description and situation development. This foundation of data from the sub-questions was integrated and used to address the main research question:

> RQM: *How can an adoption framework improve uptake and use of digital agriculture by a family farming business?*

Thematic analysis of the collected data supported the population of task and situation statements in the evaluation tools, the starting and end point of the DA adoption framework. The evaluation instruments were reviewed by the teams using the iterative Delphi method to gain consensus. Descriptive statistics were used to support the development of themes and a scoring system for the evaluation tools.

The highest standard of ethical consideration was implemented at all stages, with all participants providing written consent before the commencement of data collection. Ethical standards and data storage requirements met the standards as prescribed by the UNE. The ethics approval (approval number HE18-200) is provided in Appendix A.

4.1 Background and Context

As discussed in Chapter 1, an interest in the adoption and the ongoing use of modern technology and approaches by farming businesses have been entrenched in this researcher's work life for over 30 years. Running a technical communications business from a farm in South Australia, the researcher has had considerable experience of building the trust of the farming community to share their experiences, usually using remote interviewing techniques by phone and email. Her personal experience of successful technology adoption by farming businesses, including new crop varieties, improved livestock nutrition, no-till farming practices, GPS guidance and autosteer, has reinforced her belief in a farming business's ability to change when the technology meets its needs. Equally, her inability to persuade many farming businesses, including her own family, to embrace digital approaches in their already successful businesses has exposed the researcher to arguments regarding the practicalities and risk of change.

Between the adopters and non-adopters of DA sits a group of farming businesses struggling to know how to change. These businesses want to move beyond precision techniques that improve accuracy and pertinence of input allocation. However, they are overwhelmed by the complexity of digital technology, and this is exacerbated by their lack of digital literacy and/or access to skilled support to implement change (Barry et al., 2017; Lamb, 2017; Llewellyn, 2014). As editor of the publication *Precision Ag News* for 16 years, the researcher regularly reported on such issues. These experiences, together with living and working in a rural community that depends on unreliable mobile phone coverage and satellite broadband technology for connectivity enable her to empathise with those working in or with farming businesses in a way that would be impossible for a researcher who had lived and worked all their life in a in an urban situation. From this exposure to technology adoption and lack of uptake of digital technology, she was confident a new approach to support adoption of DA was required and desired. The concept for a more structured approach to digital adoption emanated from this experience.

Despite working in communication and extension, which are both areas of the social sciences, the researcher's work has focussed on reporting facts emanating from objective, exploratory research. It is thus the realm of qualitative research with which she is most familiar. The subject matter of the uptake and use of DA could be tackled from an exploratory or interpretive approach depending on the substance of the research question. However, a central motivation for this study was to provide family farming businesses with practical tools to help them negotiate identified limitations that stymie uptake of DA on farm and help unlock the value of DA for their situation. It was with this experience, prior knowledge, ambitions and potential biases that this researcher came to address this research question.

4.2 Selection of Research Paradigm and Strategy

To address the research question regarding the use of a framework to promote uptake and use of DA from an interpretivist point of view, a pragmatic or constructivist perspective could have been pursued. The evaluation of a framework and its potential provision of a solution to the problem of adoption falls within the pragmatic paradigm. However, when this research was initiated, there were no guiding frameworks for adoption of DA by family farming businesses. Consequently, the framework needed to be created and tested for validity and appropriateness, which demanded a constructivist perspective. It was important to acknowledge that once developed, the framework would require rigorous testing by a larger sample to allow statistical approaches of validity and reliability to be applied. Using the Yamane equation (Israel, 2003) and based on the estimated population of Australian broadacre/mixed farmers (National Farmers Federation, n.d) this validation would require a sample of approximately 400. This second level of testing and development is identified for future research.

The creation of such a framework requires knowledge and experiences to be shared, interpreted and validated; the aim being to produce a framework that is acceptable, relevant and useful for family farming businesses. To achieve this aim, a social constructivist paradigm guided the methods used to develop and confirm the proposed framework. To develop a credible adoption framework for future validation, a research strategy was required that worked closely with the farming businesses to allow them to guide the development of relevant and suitable solutions. Fulfilling this aim necessitated ongoing data collection with known, rather than anonymous, participants. Based on these requirements, an action research approach was selected.

Industrial action research and action science both offered potential research strategies for addressing the research question. However, it is with a soft systems approach that it sits most comfortably. Soft systems refer to people—the participants as the system—rather than the technology or hard systems. This approach employs the researcher as a discussion partner in a real-world situation. With the participants, the researcher generates situation models, which are used to question participants to understand their circumstances and suggest solutions to change the situation (Kemmis et al., 2013).

The researcher's desire to develop practical solutions designed in collaboration with potential users, rather than theory creation, led to the use of a mixed methods approach (Figure 4.1). This approach is reflected in each stage of the research: data collection, analysis, interpretation and evaluation to generate the evaluation instruments and Change Guide. Contextual data were gathered using quantitative (surveys) and qualitative (video tutorials and exit interviews) instruments. In Figure 4.1, the qualitative data instruments are denoted by the use of capitals letters as is convention for the dominant element of a mixed methods design. These instruments enabled remote data collection using consistent and time-efficient processes. The embedded element of the research addressing sub-question RQ3 was with a separate population of providers of DA technologies and services (denoted by the green shape). The semi-structured interviews were analysed for themes and layered with the data gathered using surveys and the video tutorials from family farming business to provide rich contextual data. Data from the qualitative surveys, semi-structured interviews and video tutorials were combined to support the creation of the task and situation statements in the evaluation tools. Data from exit interviews were used to validate the evaluation tools and research process.

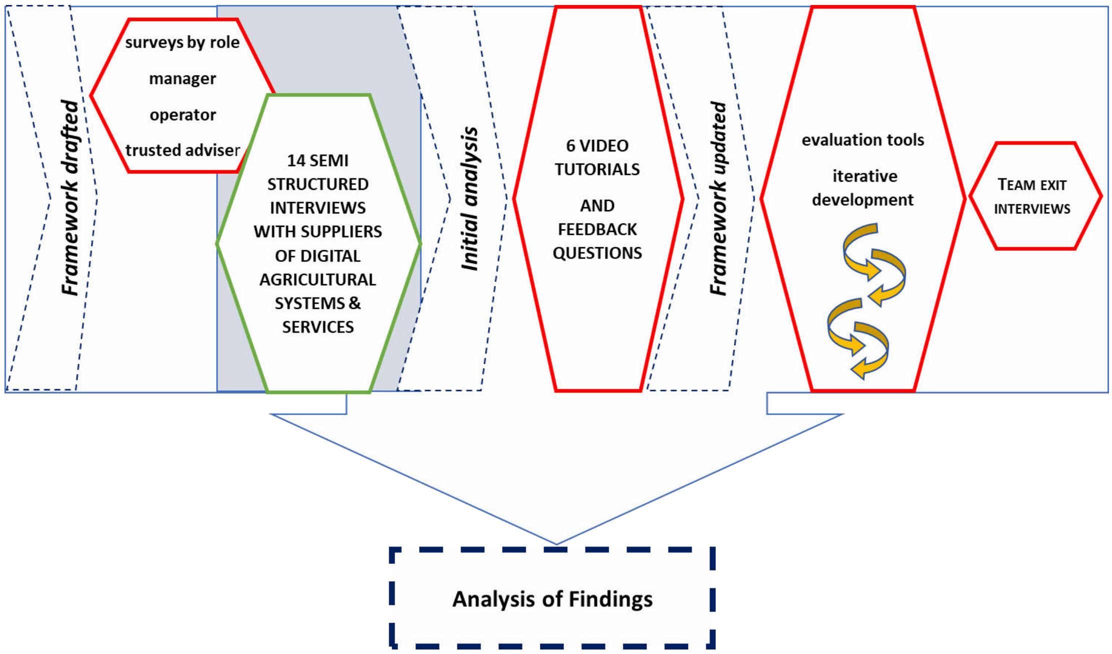


Figure 4.1

Representation of the Mixed Methods, Sequential Research Design with an Embedded Concurrent Element

Note. QUALITATIVE (UPPER CASE) and quantitative data collection (lower case). Red shapes = data collection with Farm Business Teams. Green shape = data collection with Commercial Providers.

4.3 Foundation Models

Agriculture, like other industry sectors, has fallen into the technology trap, placing the technology rather than people at the heart of adoption (Bramley & Ouzman, 2019; Kane et al., 2017; Miller et al., 2018). Although decisions to adopt an innovation are driven by management, the implementation of adoption is ultimately controlled by operators, who through their use of the innovation are directly affected by the change. Consideration for interaction between the process to be changed, the technology supporting the change, and the people driving the change is vital for successful change. Kerrigan (2013) termed these three components the triad for change. In the triad, the term process relates to both the systematic steps required to achieve change and the integration of the technology into current processes. Agricultural production, like manufacturing and software design, is full of processes; events that occur sequentially or concurrently and are required to achieve a goal. Seeding, breeding, shearing and harvesting are examples of on-farm processes that fall into the annual cycle of broadacre crop or livestock production. However, process or systems management is a term infrequently associated with agriculture, especially broadacre, rain-fed systems. Despite this process, thinking must be occurring informally as there are many very successful family farming businesses.

Three foundational models were incorporated into the research design and used to develop the framework and evaluation instruments to support a more systematic approach to digital agricultural adoption:

1. Change management—to support the people aspects of change
2. Diffusion of innovation—to validate the business decision to adopt or prevent inappropriate adoption
3. Maturity modelling—to define levels of attainment against which the current and future state can be assessed, and to qualify if change has occurred.

As formalised 'process thinking' is uncommon in agriculture, it follows that the implementation of formalised process approaches such as maturity modelling and change management is also uncommon in family farming businesses. However, based on extensive reading in the literature of their application in other industries, each was considered to offer valuable structural elements to help focus, drive and deliver digital agricultural adoption.

4.3.1 Change Management

With its heritage in action research, change management offers a structure against which to guide change, to increase the selection of appropriate changes, and engage the people who will implement the change to help ensure success. The ADKAR change management framework consists of five sequential steps: awareness, desire, knowledge, ability and reinforcement (Hiatt, 2006). The initial step begins after the required change has been identified. All five elements must be fully addressed for a change to be successfully realised. While the steps are sequential, at each step, reflection and realignment of needs, attitude and knowledge can occur to improve the outcome. Understanding an individual's self-efficacy—their belief in themselves to determine and deliver change—underpins change management and action research theory. Kane (2019) clearly identified people in any business as key to digital transformation, in the same way that Hiatt (2006) placed people at the epicentre of successful change management. These examples from outside agriculture reinforce the need to examine technology adoption in agriculture from a bottom-up, people perspective. The ADKAR approach to change management is focussed on the psychological aspects of adoption. It provides an approach to address the impact and implementation of change with all members of the family farming business.

4.3.2 Diffusion of Innovation

Adoption is primarily recorded as the point of uptake of an innovation, with various methods used to assess the success or failure of technology adoption while highlighting the human or technological factors that have influenced the outcome. Various innovation models have been developed, with different models focussing on different adoption drivers. The TAM (Pierpaoli et al., 2013) centres on technological factors, while diffusion of innovation theory (Rogers, 2003) considers the interaction between human and technological factors on adoption. Both theories have been used with agricultural technology adoption. Two criticisms levelled at both of these theories is that they bias adoption over the choice not to change; and consider adoption as a single event.

In response to these criticisms, Rogers (2003) evolved the theory by developing an innovation decision pathway consisting of five sequential steps: knowledge, persuasion, decision, implementation and confirmation. Each step is influenced by the adopters' innovativeness; communications from advertisers, educators and influencers in their networks; and their perception of the attributes of the technology. Rogers (2003) defined these attributes as relative advantage, compatibility, complexity, trialability and observability, which can occur in any order, concurrently or sequentially. The innovation decision identifies that adoption occurs over time and incorporates the option to decide not to adopt or to reverse the adoption decision. These steps in the adoption decision would be executed by the farm management team.

4.3.3 Maturity Modelling

Process and people maturity modelling was initiated by the Software Engineering Institute at Carnegie Mellon University (Curtis et al., 2009). The CMM and people capability maturity model (P-CMM) are continuous improvement models to achieve best practice for production processes and workforce efficiency. Industries that have used maturity models report improvements in productivity, product quality and profitability, as well as reduced time to market and increased customer satisfaction. Each model consists of a set of sequential steps that define the priorities that need to be satisfied before progression to the next level can occur. In this way, each step guides and measures progress from an ad hoc or initial state, eventuating in a state known as optimising. Numerous spin-off models based on CMM and P-CMM have been developed for specific industries and situations (de Bruin et al., 2005) but each aims to combine process and people improvement to harness a culture of excellence. At the beginning of this research, no maturity models for farming process or people in a family farming business had been developed. This research applied the first four of the six phases of creating a maturity assessment model as laid out by de Bruin et al. (2005): scope, design, populate and test, deploy and maintain. The deploy and maintain phases were beyond the scope of this research.

4.4 Framework Development

For successful change, the business and the people need to be working in harmony but have separate paths for responsibility and action. Delineating the needs of the business and the wants of its people can be difficult in family farming businesses with flat management structures (Fulton & Vanclay, 2011). A conceptual three-part adoption framework was designed to align the people and the business facets of adoption (Figure 4.2). The conceptual adoption framework consisted of two evaluation tools—one for people and one for business process—and a stepwise Change Guide. An iterative process was used to evolve the framework from a conceptual model to a practical tool. Each part of the framework needed to meet four criteria:

1. quick and easy to use
2. relevant to the individualistic nature of a family farming business
3. support clear direction on how and when to initiate appropriate digital adoption
4. offer a way to evaluate digital change and improvement.

The stepwise Change Guide brought together the five steps of ADKAR (awareness, desire, knowledge, ability and reinforcement) with Rogers's (2003) five stages of innovation decision (knowledge, persuasion, decision, implementation and confirmation) (Figure 4.2). The business elements were slightly offset as the investment in change occurs after the business recognises the need to change, even if that need is identified by a person outside the management team. The people steps are in the top half of the Change Guide to highlight their importance and ultimate influence over successful change. The two-way diagonal arrows show the connection and priority between each step in the two halves of the Change Guide. The parallel pathways are both influenced by the common factors of influencers and communications, and the whole process takes time, progressing from left to right. Initially, this part of the framework was generic and could be used by a family farming business to guide digital and non-digital adoption projects.

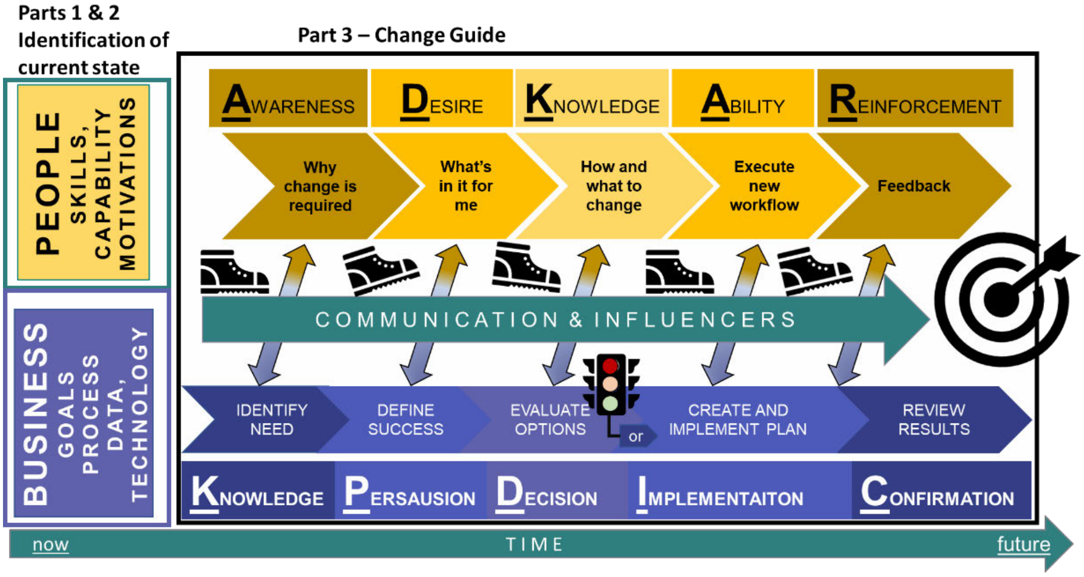


Figure 4.2

The Conceptual Three-Part Adoption Framework Designed for Family Farming Businesses

Note. Each part is contained in a box. The two halves of the Change Guide are (upper) change management and (lower) diffusion of innovation decision.

The evaluation tools needed to be specific for use with digital adoption by providing a structure against which to assess the digital maturity of the people and the digitalisation of the farming business process. The strengths and weaknesses identified by the evaluation tools were among the considerations when using the Change Guide for a specific digital change. These tools became the main focus of the research as no structure to assess the current digital state of the people or the farming business processes existed. The evaluation tools were designed to provide a clear and simple way for individuals and family farming businesses to evaluate their current and change state using a maturity approach. The development of the tools is described in detail in Section 4.7.

4.5 Bonding the Study

This section details how and why decisions regarding the setting, industry sectors and characteristics of the farming and commercial participants were made and how the participants were recruited. Ethical issues and how these were addressed are also presented.

4.5.1 Setting

The target of the research was confined to broadacre cropping and livestock producers in the winter rainfall dominant areas of southern Australia; below a latitude of 30 degrees south (Figure 4.3). Commercial participants were required to operate in the same production sectors and regions but might also work in other sectors, parts of Australia or the globe. These sectors and Australian region were selected as they:

- contained most cropping and grazing businesses by number in Australia
- had similar production cycles and periods of peak labour demand
- enabled the framework to be evaluated for a diverse range of systems
- were most familiar to the researcher.

Confining the research to farming businesses in these sectors and region enabled engagement with participants to be organised to avoid periods of peak seasonal work, such as seeding, harvest and shearing, as these occurred at similar times across the region. The researcher's familiarity with production systems in this region offered benefits in relation to creating context-specific tools and sourcing participants.

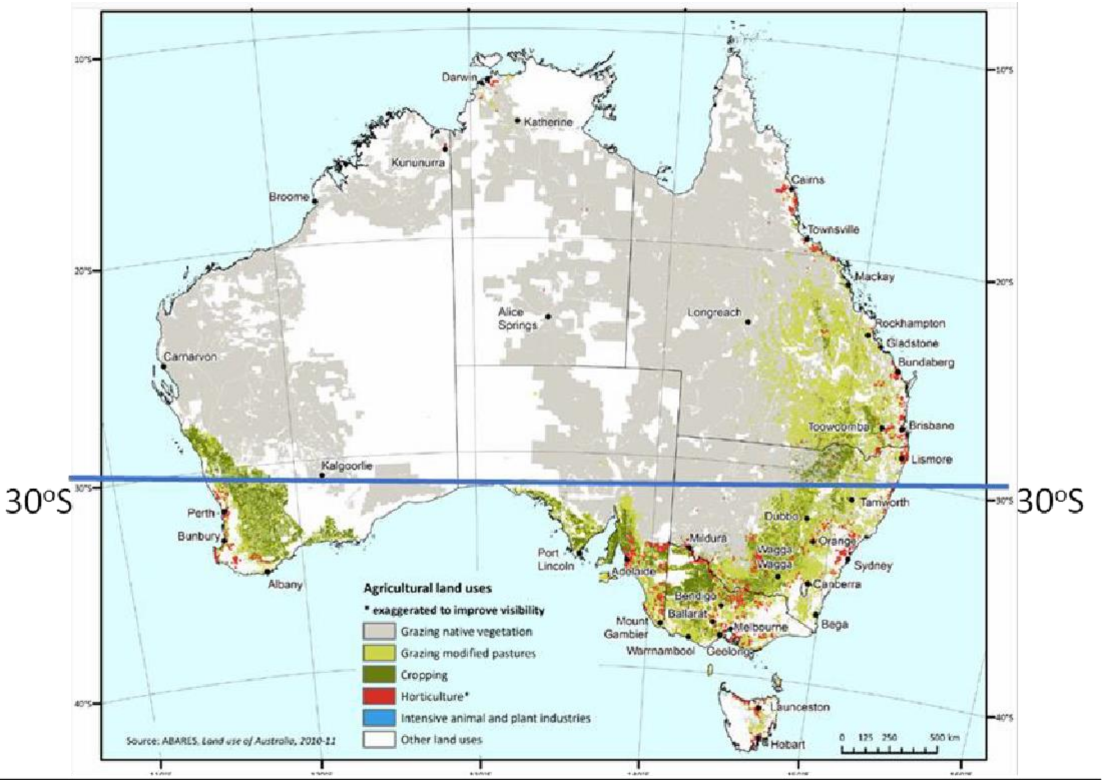


Figure 4.3

Australian Production Sectors by Location. (Australian Bureau of Agricultural and Resource Economics and Sciences, 2016)

Note. Participant invitations were distributed in areas identified as *grazing modified pastures* and *cropping* below latitude 30°S.

4.5.2 Farming Team Recruitment and Participants

Farming businesses are dominated by family-run operations with small numbers of employees who often lack higher education or specialist digital skills (National Farmers Federation, 2017; Zhang et al., 2017). To achieve the greatest impact, this research purposefully selected to work with family farming businesses.

However, it was noted that this structure required specific considerations because of the complex interrelationship between the farm, the family and the business when trying to achieve change (Fulton & Vanclay, 2011). In addition, reflection was needed because farming businesses commonly consider their situations unique (Vanclay, 2011). To overcome the shortcomings of knowledge and availability of family members, specialist skills are often supplied by external trusted advisers, when available. Such third parties have been shown to be highly influential in the successful uptake of new technology (Eastwood et al., 2017; Kutter et al., 2011; Llewellyn, 2014). To address these issues, an inclusive approach to the data collection was initiated, involving internal and external influencers of the family farming business.

To develop a framework that could assist in moving a family farming business from their current to their desired use of DA, a detailed understanding of current business practices and the people in their business was essential. Consequently, known rather than anonymous participants—both internal and external members of a business—were needed to provide data for this research.

In the ethics application, the following inclusion/exclusion criteria had to be met to participate in the research.

Inclusion:

- anyone over the age of 18
- farming business located in the winter rainfall region of Australia
- any business in cropping, mixed farming, broadacre beef or sheep production with more than two members in the management/production team struggling to adopt DA
- any business that met the other inclusion criteria and worked with a third-party adviser.

Based on these requirements, the sample was stratified into three roles—Manager, Operator and Trusted Adviser—and purposive sampling was used to select participants to provide the most pertinent, complete and detailed information. The group containing these three roles was called the 'Farm Business Team'.

To gain an in-depth understanding of the farming businesses from the perspective of each participant, yet within the time constraints of the research, the aim was to work with a minimum of 3 and maximum of 20 teams. This desire to sample beyond a single member of a business, namely *the farmer*, created challenges in team recruitment, especially in engaging the external trusted adviser. Many trusted advisers are sole traders and lack time for additional work. If an adviser did not sign up when requested, the farm management appeared reticent to insist on the adviser's voluntary involvement. After considerable effort, five complete teams were recruited between August 2018 and February 2019.

A purposive sampling approach was employed with invitations seeking farming businesses struggling with the adoption of DA. Invitations to participate in the research were distributed via three methods:

1. farming group newsletters and social media accounts: two national, 15 in South Australia (including one group of livestock consultants), 15 in Western Australia, three in Victoria, and one each in Tasmania and New South Wales—a total of approximately 1,500 addresses
2. agribusiness and grower levy body communications: 9 including via the researcher's AgriKnowHow website and Twitter account (1,124 followers)
3. direct approaches from the researcher: 47 contacts, of which 15 were gathered at a display stand at the Grains Research and Development Update in Adelaide in February 2019. This is annual conference for leading farmers and agronomists (Figure 4.4).

Figure 4.4

Participant Recruitment Display used at a Farming Event

Over 20 farming businesses showed strong interest, with seven having at least two of the required team members complete consent forms. By the beginning of the data collection in April 2019, five complete teams were involved with a total of 18 participants (Table 4.1). All were located in South Australia: two from Eyre Peninsula, two from Yorke Peninsula and one from the South Australian Mallee. A Manager in each team allocated other members to one of three roles: Manager, Operator or Trusted Adviser. The Trusted Adviser in Team 3 went on maternity leave after the first round of data collection. This team remained in the study because the primary layer of adviser data had been collected.

The use of multiple rounds of data collection with multiple data collection instruments allowed data from this small sample to be cross-validated, and a rich description of the situation to be gathered to develop the evaluation instruments. Consequently, this sample size of 18 participants in the five teams was considered adequate for this research design.

Table 4.1

Summary of Farm Business Teams Involved in this Research

Team identifier	Production sector by value	Number of participants in each role		
		Manager	Operator	Adviser
Team 1	Mixed—livestock dominant	1	1	1
Team 2	Mixed—crop dominant	2	1	1
Team 3	Cropping plus small feedlot	2	1	1 (left after survey)
Team 4	Mixed—fodder production dominant	2	1	1
Team 5	Mixed—crop dominant	1	1	1

4.5.3 Commercial Recruitment and Participants

During the recruitment of the teams, the researcher was approached by some providers of digital services and technologies. They offered to share their experience of the barriers to adoption of DA. Literature between 2005 and 2018 was reviewed via the University of New England Library and Google Scholar using search terms including 'suppliers', 'providers', 'commercial', 'service' and 'developers'. These searches included Scopus, Science Direct and Elsevier data bases and no specific literature relating to commercial providers and barriers to adoption of DA was identified. It was thus considered valuable to address RQ3: *How do commercial providers of digital agricultural hardware, software or support services, view and address the barriers to uptake of digital agriculture?*

By addressing this question, it was hoped that similarities and differences between users' and suppliers' perspectives on the barriers and solutions to digital adoption might be understood. By gaining an understanding of the perspectives of both groups, new methods for unlocking the value and overcoming the barriers to adoption might be found. These findings contributed to development of the adoption framework and supporting evaluation tools.

Through the researcher’s network of contacts, as well as additional associates provided by the providers that joined the research, 20 providers were invited to participate in the research, with 14 agreeing to partake in semi-structured interviews (Table 4.2).

The criteria for inclusion for commercial providers were:

- at least 3 years’ commercial operation in the digital agricultural sector in Australia
- a significant, recognised supplier in the agricultural sector
- currently offer hardware, software, services or a combination of these items in the farming sector in the southern area of Australia
- service grain and/or livestock industries.

The criteria for exclusion were:

- agtech start-up
- only servicing dairy livestock.

One company provided participants from its USA and Australian head offices, who were interviewed together.

Table 4.2

Anonymised Details of the Commercial Providers

Type	Sector	Initial year of offering DA in AU	Indicator of market share/significance
Hardware & service	Cropping & viticulture	2009	700–800 businesses
Hardware & software	Cropping & livestock	2006	Not stated
Hardware & software	Horticulture, irrigated perennials	2016	7,500 regular users of app
Hardware, service & software	Cropping	2000	Not stated
Hardware, software & services	Dairy, turf, horticulture, cropping	2009	25% cropping
Service	Cropping, livestock, horticulture	2017	165 advisers; 40,000 clients
Service	Cropping	2003	350 clients; 40–50 using PA
Service	Cropping, pasture, horticulture	2009	600 clients; 100,000 ha
Software	Cropping	2008	~80% of agronomists; 15% cropping farmers
Software	Livestock plus cropping	2014	2,000 in AU
Software	Cropping, pasture, horticulture	1999	36,000 farmers via agronomists
Software & service	Cropping, horticulture, irrigation	2000	4,000 clients, 4 million ha, AU
Software, service	Cropping	2003	2,000 users
Software, service	Cropping plus livestock (new)	1996	800 clients

Note. AU = Australia; DA = digital agriculture.

4.5.4 Ethical Considerations

Before involvement, each Farm Business Team participant and each Commercial Provider signed a consent form, having received an information sheet detailing the aims of the research; the type of participation; the anticipated time commitment; the type of data that would be gathered; and how they would be treated and stored (see Appendix B, Farm Business Team; Appendix C, Commercial

Provider). They were also informed that participation would be reported anonymously. Other ethical considerations were related to questions regarding the working relationships between members of the business team and details about the business's finances and third-party charges. Because of the sensitive nature of this information, questions on these topics were avoided. Recruitment communication material and data collection instruments were approved by the UNE Human Research Ethics Committee (see Appendix A).

4.6 Data Collection

There were three data collection instruments employed: electronic surveys; online video tutorials with email or text feedback; and semi-structured interviews conducted via video link (Figure 4.1) The choice of instrument was based on the need to maximise the efficiency of quality data collection and minimise the imposition on the time of the participants. Data collection was initiated in October 2018 and completed with exit interviews in February 2021. Data collection occurred in chronological order from left to right in Figure 4.1, with the embedded commercial interviews occurring concurrently with the surveys. Results from the data collection instruments were used to populate and refine the evaluation tools.

The research design and the location of the participants required all data collection to be executed remotely. At the extremes the teams were spread 815 km apart; similarly, commercial participants were located in six different states across Australia. The use of remote approaches for data collection limited the researcher's ability to be embedded in the research but enabled the individual team members to respond independently and at a time of their convenience. The researcher was known of—if not known personally—by participants because of her previous roles in the grain and livestock industry across Australia. This knowledge facilitated engagement and a rapport with the participants.

Four stages of data collection occurred with the farming teams. Three stages were reported as individuals via an initial survey, video tutorials, several rounds of testing and refining the evaluation tools. The exit interviews were undertaken as a team. Each commercial participant's data were collected via a single semi-structured interview.

4.6.1 Surveys

Three separate surveys were distributed to capture specific data of relevance to each participant category: Manager, Operator and Trusted Adviser (see Appendix D). Each survey was tailored to a team member's role and designed to be used with known participants. Survey questions were designed to reflect the types of responsibilities and job specifications of each role. Consequently, not all questions were posed to every role. This design was aimed to improve the relevance of responses by role and maximise information gathered with minimum imposition on the participants. The objective of the survey was to provide a consistent method to capture and quantify details about:

- the farming business and its current and anticipated use of DA
- the technological and human barriers that might prevent the target being achieved at that point in time
- their digital aspirations.

The survey instruments were designed in and circulated using the survey software Qualtrics (between September 2018 and July 2019), with question content informed by the six barriers to adoption of DA (Leonard et al., 2017) (Figure 4.5). The majority of questions were closed using a range of formats to retain engagement

(Dolnicar, 2013), including matrix tables, multiple choice, slider bars and free text entry. Answers relating to attitude and perception used five- or seven-point Likert scales. The questionnaires were long (Managers, 54; Operators, 30; and Trusted Advisers, 41 questions) and the design was aimed to keep participants engaged; gather a wide range of information quickly; and meet the data collection objectives. The appropriate survey was circulated to participants following one round of pilot testing by several non-participating Managers, an Operator and a Trusted Adviser.

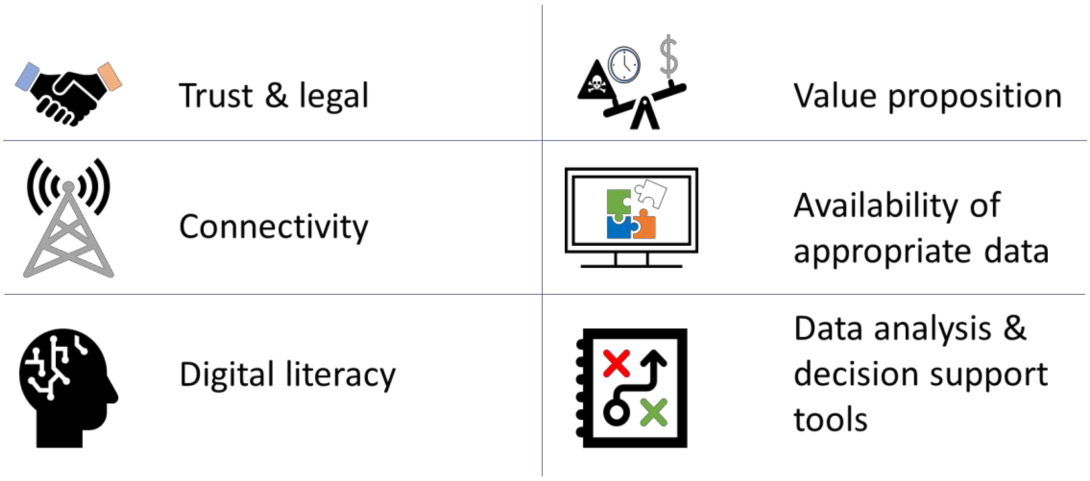


Figure 4.5

Six Barriers to Adoption of DA Used to Inform Surveys and Semi-structured Interviews (Leonard et al., 2017)

4.6.2 Commercial Interviews

The semi-structured interviews were conducted either by video call (n = 10) or telephone (n = 4). The objective of the interviews was to identify the Commercial Providers' attitudes to the six barriers to adoption (Figure 4.5) and how they were addressing these in their businesses. In both scenarios, with the consent of the participant, the interview was recorded as audio and video when used. All participants consented. Interviews occurred between October 2018 and February 2019. A total of 18 hours of interviews was transcribed by the researcher. Each interview was constructed around the six barriers to adoption (Figure 4.5). Details of these barriers had been emailed to the Commercial Provider prior to the interview. During the interview, each Commercial Provider was asked to rank the barriers from lowest to highest from the perspective of their business.

4.6.3 Video Tutorials

Video tutorials provided an instrument for sharing information and ideas, and posing open questions to team members. The objective of the video tutorials was to assess the first step in the Change Guide (for the business to identify a need and nominate a change captain) and in so doing gather information to support the statement development for the evaluation tools. Six videos were produced, each with a supporting open question, and each was distributed as a link to the AgriKnowHow YouTube site (see https://www.youtube.com/channel/UCmpt2F8u_CTakMbWP0N8c9Q) between April and September 2020 (Table 4.3). Questions were answered by email or text message, with each participant free to choose their preferred feedback platform. Feedback was not provided via the YouTube platform, to ensure participant anonymity among teams. Questions 2 and 3 in Table 4.3 were designed to test the initial steps of the adoption framework. The feedback was used to modify the framework and populate the evaluation tools.

Videos offer an excellent way to clearly communicate complex ideas in visual and engaging ways. Other benefits of videos are that participants can watch at a time of their choice and can re-watch to help clarify, remind and reinforce information. In each video, a concept was described, followed by a question relating the concept to their business, and concluded with a humorous video clip or cartoon to ‘put a smile on your dial’.

Table 4.3

Themes Presented and Questions Posed in the Six Video Tutorials

No.	Video theme	Question	Duration (seconds)	Date distributed
1	The big question—framework introduction	Do you need more info? Please contact me.	392	29 Apr 2020
2	What is digital agriculture?	Which process would you like to digitise first and why?	345	04 May 2020
3	The role of the change captain	Who would you nominate as change captain and what roles do you see for others in your team?	403	02 Jun 2020
4	The art of agile management	What is stopping you from making the change proposed in Q2?	526	22 Jun 2020
5	Update, data flows and the digital business structure	Does this breakdown represent the core and focus management areas for your business?	620	20 Jul 2020
6	Digital Knowhow Self-assessment tool—feedback	How well do you think your score and the definition reflect your digital knowhow?	502	23 Sep 2020

4.6.4 Exit interviews

An exit interview was completed via Zoom with each Farm Business Team, ideally with all team members. Teams 2, 3 and 5 had all members involved, Team 1 was missing the Trusted Adviser and Team 3 had only two Managers present. Each interview was recorded, with participants' permission. The objective of the interview was to thank the participants for involvement, illustrate how the tools were constructed, and gather feedback on tools and the research process. A report of their scores was emailed to the team prior to the interview. Each of these objectives was achieved using a standard set of questions supported by a PowerPoint presentation (Appendix E). All interviews were held in February 2021.

4.7 Evaluation Tools

The evaluation tools provided the part of the adoption framework that was highly specific to DA. The tools would provide a simple but structured approach for a family farming business to understand the current status of digital maturity of the people and processes in the business and how it changes over time. Used at the start of the change process the score provides a baseline maturity against which change be measured. By repeating the tool at a later point in time, the new score identifies if a change in digital capability or process has been achieved; hence the genesis of the Digital Knowhow Self-assessment (DKSA) and Farming Business Digital Process Maturity (hereafter, the DPM) tools. The tools were based around the concept of relative estimation (Measey et al., 2015) using rapid, simple tests to provide an indication, rather than an absolute result. This objective allowed large numbers of variables to be explored rapidly, with responses requiring only tacit knowledge.

4.7.1 Digital Knowhow Self-assessment Tool

To operate in a digital workplace, including on farm, some level of digital competency is required, depending on roles and responsibilities (KPMG, 2019b). Digital literacy was one of the six barriers to the adoption of DA identified in the *Accelerating precision agriculture to decision agriculture: Enabling digital agriculture in Australia. Summary Report* (Leonard et al., 2017) (from here on referred to as the P2D Summary Report) and affirmed by initial analysis of the survey and commercial data in the current study. As part of the adoption framework for DA, a tool was required to indicate an individual's digital competency and to measure how this changed overtime.

The aims of development of the DKSA were to:

1. provide a quick, reliable and valid method to quantify digital knowhow and monitor change
2. create a self-assessment process suited to multiple roles within a family farming business
3. establish a digital knowhow maturity score aligned to a stage gate, (specific criteria).

By using the DKSA tool with current and future team members, a farming business should be able to compare the digital competency of the individuals in the business; highlight strengths and weakness; and identify training required to complete specific tasks. Conversely, results may identify skills in the team that are not currently utilised. The self-assessment tool in this research was designed to assess digital skills in relation to tasks, specifically relevant to people working in grain, broadacre livestock and mixed farming systems.

Nickols (2011) defined a task as a time-bound activity that can be taught; and a skill as an inferred capability that can be developed. The use of the term knowhow indicates that the framework addressed more than attainment of the skills to complete a task; it also reflected the characteristics of trust, confidence and value, as these characteristics influence successful adoption and sustained change (Hiatt, 2006) and are embraced by the term attitude.

The DKSA tool was developed in Microsoft Excel, then transferred to Qualtrics and presented to the participants as a survey that could be accessed via a mobile phone (Figure 4.6) or web browser. The DKSA went through three rounds of testing (Alpha, Beta and Final), using the iterative Delphi method to gain consensus, with all team members. Delphi is an action research analysis method used to generate consensus among experts on the most appropriate facets of a project, or terms to describe a phenomenon. It uses a system of present, report, modify, re-present to gain consensus. At each round of testing the predominant feedback from the previous round was incorporated and reappraised to gain consensus. Appendix F contains the fully populated Final version of the DKSA tool, which required a total of 131 responses including 15 for the validation questions. For each version, a link to the survey was sent directly to each team member. All 17 remaining participants in the five teams completed each version.

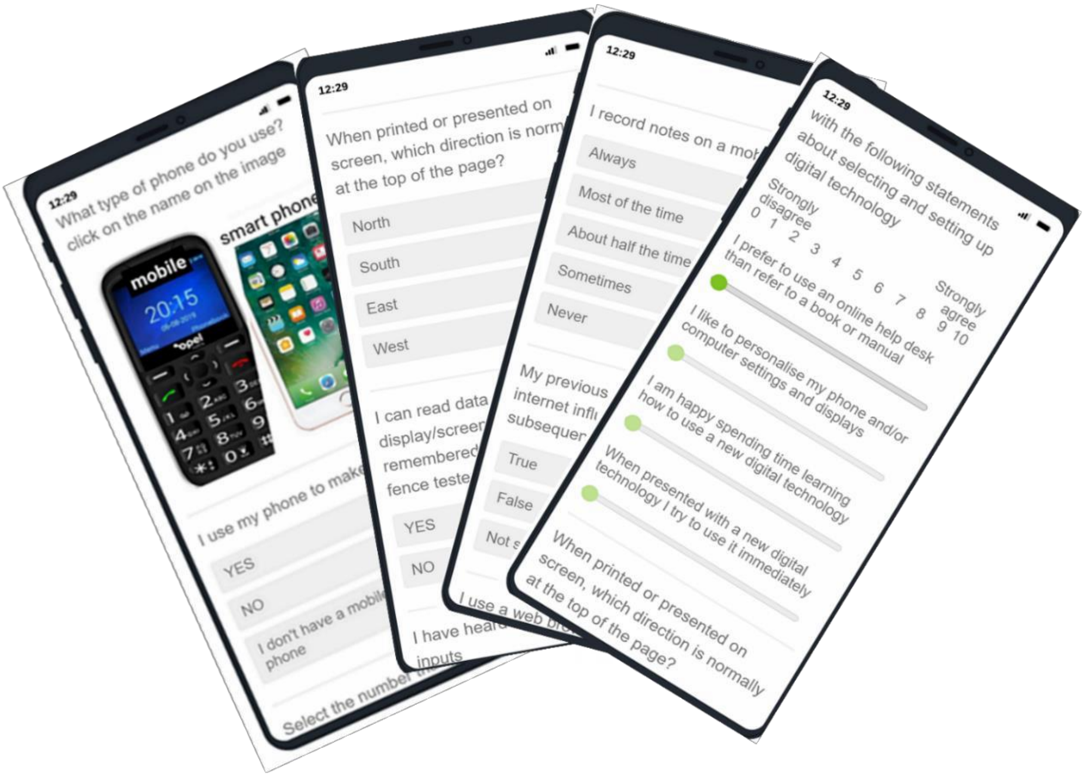


Figure 4.6

Screenshots of the Mobile Version of the DKSA User Interface Illustrating Different Question Formats

The self-assessment tool contained four parts, which are illustrated in Figure 4.7. The following explains how these parts were established:

1. Components—Skills: communication and collaboration, select and setup, plan and organise, monitor and collate, analyse and interpret, decide and act, safety and security

2. Subcomponents—Characteristics: knowledge, ability and attitude

3. Stage gates: minimal, directed, capable and initiating (definitions and score)

4. Populate—Task statements: one statement or question for each skill, by each characteristic, by stage gate.

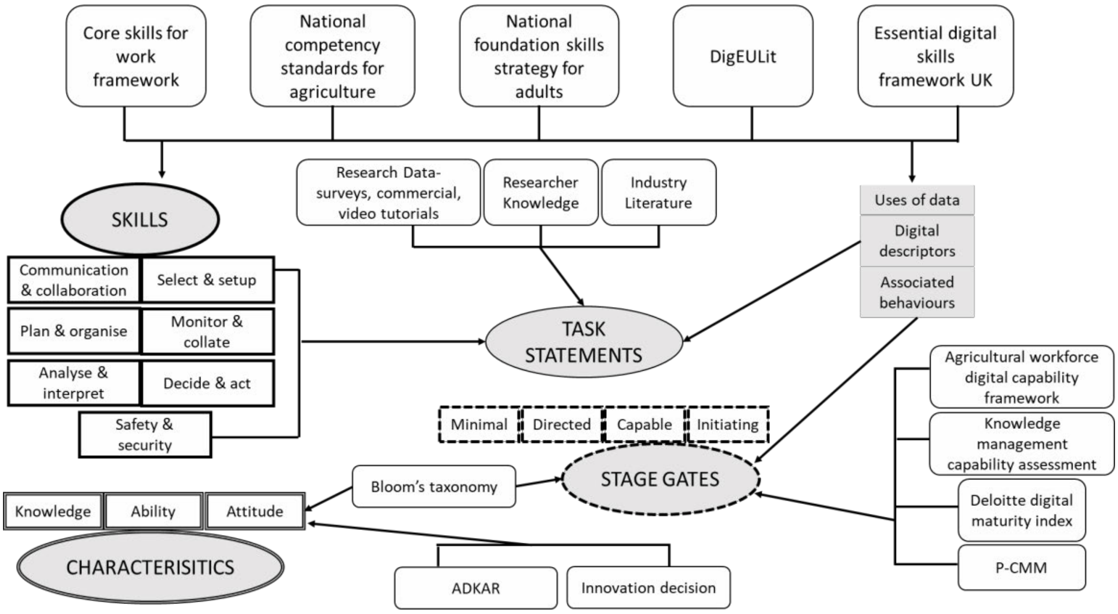


Figure 4.7

Resources and Their Use to Construct the Digital Knowhow Self-assessment Tool for Mixed Farming

4.7.1.1 DKSA Components—Skills

Five existing frameworks and strategies of relevance to digital skills and agriculture were evaluated; three from Australia and one each from the UK and EU (Table 4.4). These frameworks laid out the skills, cognitive processes, knowledge types, actions, digital descriptors and associated behaviours required for operation in a digitised workplace.

Table 4.4

The Five Education and Skills Frameworks Used to Create the DKSA Tool for Agriculture

Title	Country	Release Date	Key objective	Developer	Source reference
The Core Skills for Work Developmental Framework	Australia	2013	A set of non-technical skills, knowledge and understandings that underpin successful participation in work.	Australian Government Department of Education, Skills and Employment	https://www.dese.gov.au/skills-information-training-providers/resources/core-skills-work-developmental-framework
National competency standards for agriculture	Australia	1998	A qualification based on units of competency to design courses to make people job ready. Set of standards based around specific tasks.	Australian National Training Authority	https://training.gov.au/TrainingComponentFiles/NTIS/RUA98_1.pdf
National Foundation Skills Strategy for Adults	Australia	2012	For the purpose of this strategy, foundation skills are defined as a combination of English language, literacy and numeracy—listening, speaking, reading, writing, digital literacy and use of mathematical ideas; and employability skills, such as collaboration, problem solving, self-management, learning and information and communication	Department of Education, Skills and Employment	https://www.dese.gov.au/skills-information-training-providers/resources/national-foundation-skills-strategy-adults

			technology (skills required for participation in modern workplaces and contemporary life).		
DigEULit	European Union	2006	This project, funded by the European Community eLearning Initiative, has the task of defining digital literacy and developing a framework and tools for digital literacy development in European educational settings.	Allan Martin and Jan Grudziecki	https://doi.org/10.11120/ital.2006.05040249
Essential Digital Skills Framework	United Kingdom (UK)	2018	This framework is intended to be used by everyone in the UK involved in supporting adults to improve their essential digital skills.	UK Government	https://www.gov.uk/government/publications/essential-digital-skills-framework/essential-digital-skills-framework#content

The five foundation resources were used to identify the core skill areas associated with the collection and use of digital data and systems, irrespective of industry sector. These became the components (pillars) of the model created for this research. Each component was designed to be mutually exclusive but to capture all potential areas of on-farm digital application.

The seven components were represented by the following core skill areas:

- communicate and collaborate
- select and setup technology
- plan and organise
- monitor and collate
- analyse and interpret
- decide and act
- safety and security.

4.7.1.2 DKSA Subcomponents—Characteristics

A set of three hierarchical domain models developed by Dr Benjamin Bloom in the mid-20th century (Seaman, 2011) were the basis for the development of the three subcomponent characteristics. Referred to as Bloom's Taxonomy, the three domains are *cognitive* (knowledge/awareness), *psychomotor or action based* (ability, readiness to act) and *emotion or affective* (attitude). These three areas were aligned with the selected change management and adoption theories underpinning the Change Guide (Hiatt, 2006; Rogers, 2003) (Figure 4.7). These subcomponents are referred to as characteristics that influence digital adoption, knowledge, ability and attitude. Variation in scores between these three characteristics were used to help determine individuals' strengths and weaknesses in relation to a skill area, based on responses to statements about a specific task.

4.7.1.3 DKSA Stage Gates

To use the DKSA to assess current and changed digital knowhow, user scores needed to be related to a stage gate. Four existing people CMMs were reviewed to assess suitability of existing stage gates (Table 4.5). The models reviewed included the Agricultural Workforce Digital Capability Framework report and self-assessment approach released by Cotton Research Australia on behalf of a consortium of Australian research and development organisations (KPMG, 2019a; Zhang et al., 2019). This was the first agriculturally specific maturity framework to be published. After reviewing this, the level of questioning was considered more appropriate for corporate rather than family farming businesses; was not sector specific; and was designed to assess industry skills requirements for the development of further education, rather than focus on a specific business. Indeed, this framework helped highlight pitfalls to be avoided for a maturity tool suited to family farming businesses.

It was concluded that none of the stage gate terms in the frameworks provided the perfect fit for family farming businesses; instead the stage gate names minimal, directed, capable and initiating were selected. Each stage gate related to a range of skills, tasks and uses of digital as defined in Table 4.6. These definitions were developed with the support of the resources in Table 4.4 and Table 4.5.

Table 4.5

Descriptors for the Stage Gates in the Four Human CMMs Reviewed

Model name	Stage gate						Source reference
People Capability Maturity Management (P-CMM)	Initial	Managed	Defined	Predictable	Optimising		(Curtis et al., 2009)
Agricultural Workforce Digital Capability Framework—Training and curricula handbook for education and training providers	Foundational	Developing	Proficient	Mastery			(KPMG, 2019b)
Knowledge management capability assessment	Not possible	Possible	Encouraged	Enabled/ practiced	Managed	Continuous improvement	(de Bruin et al., 2005)
Deloitte Digital Maturity Index	Laggard	Follower	Average	Leader	Pioneering		(Deloitte, n.d.)

Table 4.6

The Four Stage Gate Definitions for the DKSA Constructed Around the Three Characteristics—Knowledge, Ability and Attitude

Minimal	Directed	Capable	Initiating
Aware of digital tools and solutions but has low confidence and ability in their use. Low level of interest in learning how to use digital tools and a minimal understanding of the issues of data security. If there is a choice they will generally opt for non-digital processes. May also have issues with eyesight and physical handling, interacting with the technology.	When shown, able to use basic digital tools and data but may need regular refresher tuition. Understands the application and potential of digital tools but has low tolerance of them, especially if they break down or malfunction. Aware of need for digital security but can lack ability to implement. Will continue to use manual systems, especially as a backup as concerned about losing data.	Uses a wide range of digital tools, platforms and data both at work and home. Able to set up and calibrate tools and to direct others in the use of digital solutions. Able to up- and download data, manage their storage and troubleshoot problems. Uses data to support day-to-day decisions. Implements data security routines. Believes digital is the way forward.	Has extensive practical experience of implementing digital solutions for a range of tasks and production areas. Integrates digital solutions to perform processes and combines multiple datasets to support decisions about strategy and production and to report on outcomes. Implements logical and secure data storage. Engages the appropriate support to enable digital solutions to be implemented across the business. Seeks out new and improved digital approaches. Shares time and knowledge to help others adopt digital tools and influence peers and developers.

4.7.1.4 DKSA Task Statements

On reviewing the five foundation frameworks (Table 4.4) and the four maturity models (Table 4.5) the actions, digital descriptors and associated behaviours relevant for a digital workplace were identified (Table 4.7). These digital descriptors and associated behaviours, together with the task- and situation-specific terms from the data collection instruments and industry literature (Australian Wool Innovation & Meat & Livestock Australia, 2018; Grains Research and Development Corporation, 2017; Henry et al., 2012; O'Callaghan, 2017), were used to develop the questions and statements relating to specific tasks that populated the DKSA. The Alpha version of the DKSA was populated by statements that required either a 'yes' or 'no' answer, rating or multiple choice. In addition to the 116 responses required for the tool, there were four multiple choice validation questions. When working with the participants using the Delphi method to gain consensus, the statements, response structure and scoring evolved, as described in Chapter 6.

Table 4.7

Actions, Descriptors and Behaviours Used to Create Statements to Populate the DKSA and DPM

Action	Digital descriptors	Associated behaviour
View	Source, access, locate, navigate, find, monitor, observe—digital content and media	Judge relevance, validity, appropriateness
Capture	Download, identify, scan, image, collect, gather, retrieve—data and audio-visual media	Understand appropriate online behaviour and security issues.
Share	Upload, communicate, integrate, plan, link, instruct and participate using digital platforms	
Store	Organise, file and secure data and digital files in a retrieval format	
Action	Adapt, apply, prescribe, create, analyse, interpret, integrate, initiate, read, edit, navigate, improve, problem solve, transact, design, use, program, process—using one or more digital technology or data sources	Implement secure and safe storage and working practices
Report	Review, react, assess, conclude and propose actions based on data, digital content and media	

4.7.1.5 DKSA Scoring

A simple additive scoring system was developed to produce an individual's total maturity score, with scoring method linked to question style. A dichotomous scoring system allocated a correct answer a score of '1'; an incorrect or 'unsure' answer received a '0' score. If a question had more than one correct answer, a point was allocated for every correct answer. Where rating options were provided these were on a 0–10 basis with a selection of zero scoring '0' and a selection of 10 scoring '10'. Four questions with multiple choice answers had a ranked scoring using Fibonacci numbers. For example, in response to the question, 'How often do you back up your data?', the options and scores were never, 0; sometimes, 1; daily manually, 3; backups automated and go to a hard drive, 5; and backups automated and go to a cloud server, 8. This ranked scoring approach aimed to clearly differentiate maturity levels. These scores were summed to produce a total score. The maximum score for the Final version of the DKSA was 360 and, for the validation sections, 167.

An equally weighted, quartile-based allocation of DKSA scores to stage gates was applied to a 0–100% scale (Table 4.8). The quartile-based score could be applied by total score or by component or subcomponent. A small difference in maximum potential score per stage gate, 89 to 91 points, occurred because of variation in question type scoring (Table 4.9). To account for this, a weighted scoring system was applied to the component and subcomponent before summing to establish an individual's total maturity stage. The weighted score was calculated by dividing the total maximum possible score, 360, by the total maximum score for the component or subcomponent. In the same way a weighted score for each component and subcomponent was produced in relation to the total possible score for items associated with the component skills or characteristics.

Table 4.8

DKSA Stage Gate Score Quartiles

Maturity stage gate	Minimal	Directed	Capable	Initiating
Quartile percentages	0–25%	26–50%	51–75%	76–100%

Table 4.9

DKSA Statement Number and Scores by Stage Gate

Maturity stage gate	Statements	Score
Minimal	20	90
Directed	21	89
Capable	23	90
Initiating	21	91
Average	21.25	90

4.7.2 Farming Businesses Digital Process Maturity Tool

The aims in regard to the DPM were to identify current and desired use of digital technologies and data in relation to specific on-farm activities and relate these to a maturity index. Using such information, priorities for digital change can be established and monitored. The DPM needed to provide a simple, reliable and valid method for farm managers to identify:

- if the data elements are in place to support digitisation and eventually digital transformation
- consistency or differences in the understanding of the current situation and the desired situation by the internal members of the business teams.

Business process management and value stream mapping were other approaches considered but rejected in favour of maturity modelling. While these alternative processes offer many useful components and have similarities with maturity modelling, they were considered too specific to a single process or too expansive—in considering the whole value chain—and thus not suited to map and prioritise areas for on-farm digital transformation. Once a farming business has initiated their digital journey, both business process management and value stream modelling might offer additional tools to improve and refine digital transformation.

Appendix G contains the fully populated version of the DPM as it was circulated to the team Managers, including the validation questions. The DPM was initially developed in Excel, converted to an online survey using Qualtrics and circulated via a link that could be accessed via a mobile phone (Figure 4.8) or internet interface. Only a single version of the content was circulated for testing by the participants as much of the iterative development had occurred via the video tutorials.

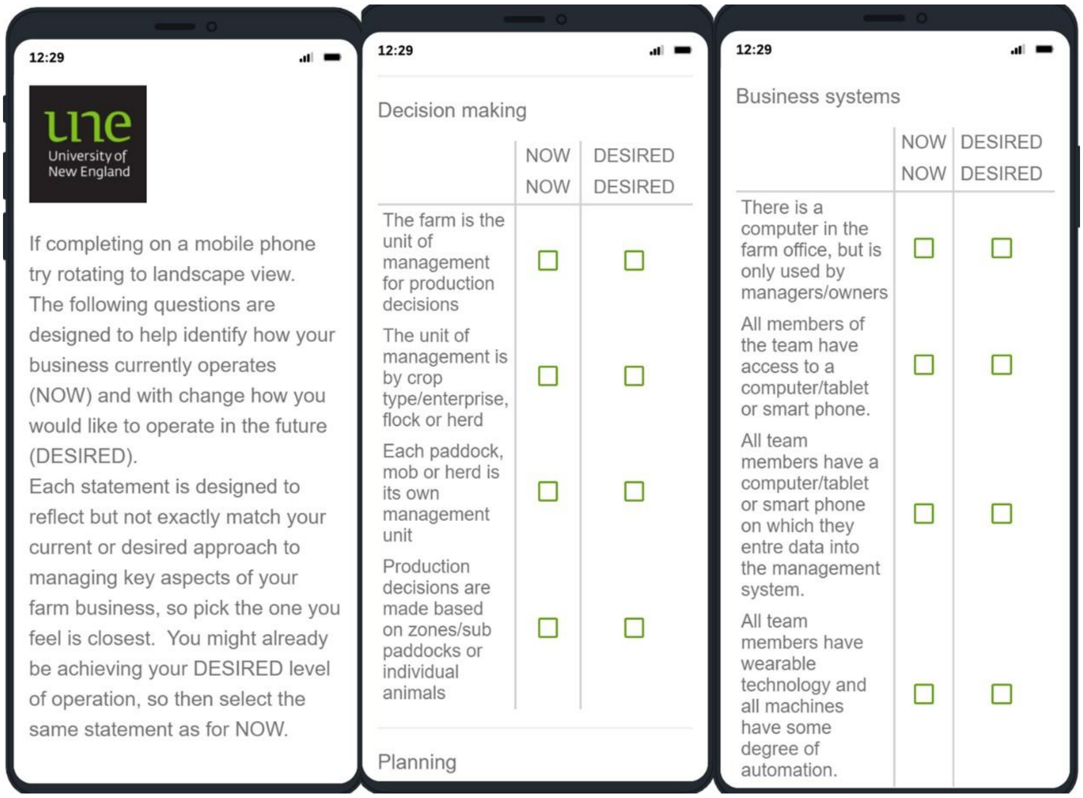


Figure 4.8

Screenshots of the Mobile Version of the DPM User Interface Illustrating the Completion Instructions and Question Format

The same development approach was applied to the DPM as to the DKSA: defining stage gates, components and subcomponents, population and scoring (de Bruin et al., 2005) (Figure 4.9).

- Components—Core business functions: business administration, production and resource management and marketing
- Subcomponents—Focus activities: administration and finance, engaging and empowering team, legal, regulatory and compliance, inventory and logistics, decision making and planning, stock control, prices, variation and weather, targets and benchmarks, farm resources traceability and quality and quality assurance
- Stage gates and scoring—manual, digitised, digitalised, digitally transformed

- Populate—Situation statements: one statement for each subcomponent at each stage gate.

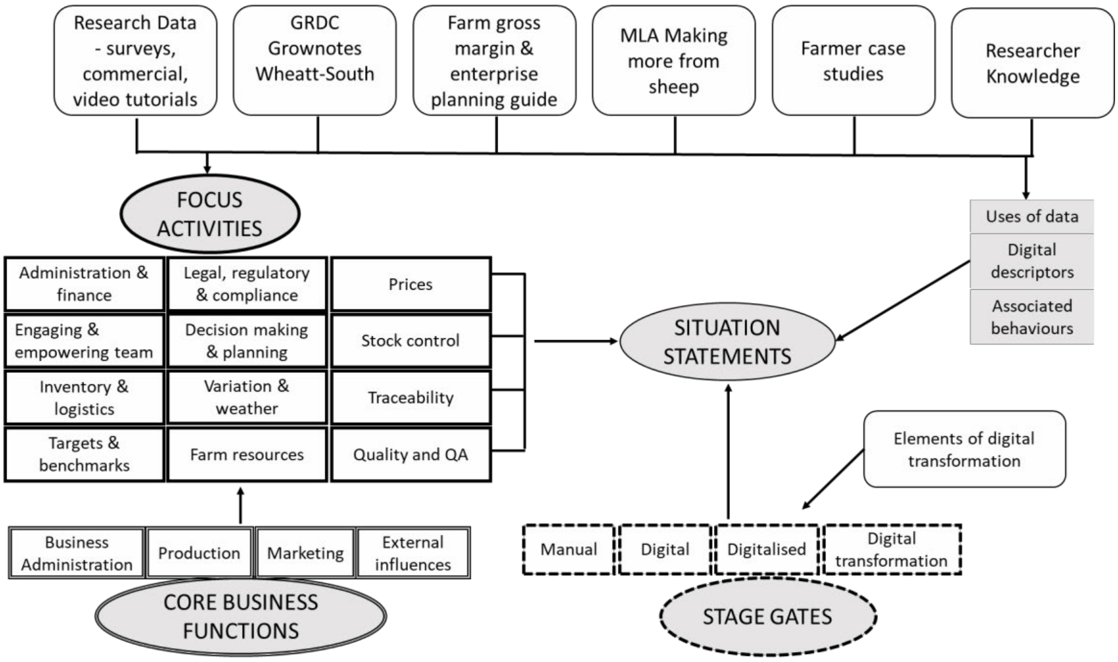


Figure 4.9

Resources and Their Use to Construct the DPM Tool for Mixed Farming

4.7.2.1 DPM Components and Subcomponents

The components and subcomponents were based around the core business functions and focus activities presented to the teams in Video 5. These were synthesised on the basis of practical farm management publications (Australian Wool Innovation & Meat & Livestock Australia, 2018; Grains Research and Development Corporation, 2017), user case studies, research data and the researcher's own farm management knowledge and experience. The evolution of the components and subcomponents is presented in Chapters 7 and 8.

The four components—business administration; production and resource management; marketing; and external influences—were subdivided into subcomponents based on the functional and enabling factors of a business. For example, a subcomponent of the core activity business administration is administration and finance, which relates to the data sources of financial records, management records, asset management, business systems and succession. These terms were refined by the teams using a Delphi method to gain consensus. Videos 2, 4 and 5 played a key role in supporting the development of the tool by providing real examples of processes that individual team members wished to digitise and why they were not initiating the change, and helped define the core and focus business areas and the datasets that would need to be integrated.

4.7.2.2 DPM Stage Gates

Numerous existing CMMs, including several with specific relevance to digital and agricultural change, were reviewed for guidance on the creation of stage gates (Table 4.10). These examples illustrate the diversity of approaches to maturity modelling. There are no hard and fast rules for the number of stage gates. None of the existing models, including those designed for DA, met the objectives of the DPM, which was being designed for use by family farming businesses. The current models were either designed to support whole of industry change or used technical language rather than the practical terms more familiar to family farming business. An alternative approach to define the stage gates and components was taken based on the need to be simple, yet specific to the aim.

Instead of creating stage gates using descriptive adjectives, the naming of the gates reflected the elements of digital transformation: manual, digitised, digitalised and digitally transformed (Savic, 2019). The definition of each stage gate included reference to four criteria: planning, use of digital, management style, and market focus (Table 4.11). These four criteria reflect the attitude to the use of data and digital technologies to support the core functions (Australian Wool Innovation & Meat & Livestock Australia, 2018; Grains Research and Development Corporation, 2017; KPMG, 2019a).

Table 4.10

Resources Used to Guide the Development of Stage Gates for the DPMT

Title	Stage gates—in ascending proficiency left to right						Date/ release	Reference
Capability Maturity Model	Initial	Managed	Defined	Quantitatively managed	Optimising		1986	https://en.wikipedia.org/wiki/Capability_Maturity_Model_Integration
Digital Maturity Index for Agriculture	Emerging	Transitional	Competitive	Transformative			2019	https://www.crdc.com.au/growing-digital-future
	Strategy & culture	Technology	Data & analytics	Capability	Data rules			
Data to Decisions CRC Maturity Index	Ad hoc	Foundational	Competitive	Differentiating	Breakaway		2017	https://www.crdc.com.au/sites/default/files/CRD18001-001%20CRDC%20P2D%20Report%20low%20res.pdf
	Strategy	Data culture	Governance	Analytic tools	Infrastructure	Digital literacy		
Deloitte Digital Maturity Index	Laggard	Follower	Innovator/ operator	Potential	Champion		n.d.	https://www2.deloitte.com/de/de/pages/industry-operations/solutions/digital-maturity-index.html
	Digital activity	Digital business	Digital capability	Dynamic capability				
Southern Australian Government Digital Transformation Toolkit	Minimal	Informal & reactive	Transitional	Customer driven			Version 4.2	https://www.dpc.sa.gov.au/ data/assets/pdf_file/0008/46565/Digital_Transformation_Toolkit_Guide.pdf

Table 4.11

Stage Gate Definitions for the DPM Tool

Stage gate	Manual	Digitised	Digitalised	Digitally transformed
Planning	Management and operations are not highly planned. Business aims are not written down.	Key management and production activities are planned and may be aligned to business aims; basic strategies are documented.	Strategies and targets are established for business administration, production and marketing activities. Performance is analysed.	Internal and external data are collected intensively, and integrated and analysed to support strategic and reactionary activities.
Use of digital	Only limited records are logged and stored electronically.	Financial and management records are computerised. Other data pools may be gathered digitally but in siloed software.	Spatial, temporal and observational data are interoperable with production and management records. Data are used across operations and activities to achieve continual improvement.	Digital processes are used to augment or replace human activities. Developments in new digital tools and processes are monitored.
Management style	Management is responsive to problems, not proactive to prevention.	Management is proactive to key business activities, but opportunities can be missed because of dealing with day-to-day problems.	Management style is proactive, inclusive and responsive to opportunities.	Management is very proactive, inclusive and quick to respond to opportunities.
Market focus	Production is focussed on total output, not quality, customer need or even profit.	Market requirements and quality are considered but total output and profit are the measures of success.	Production activities have a strong market focus and are responsive to feedback from customers.	Production and customer requirements are intimately linked, and datasets are shared up and down the value chain to improve profitability, efficiency and safety.

4.7.2.3 DPM Situation Statements

A situation statement was created for each maturity level by focus activity, resulting in 88 statements. The approach taken for the development of task statements was replicated for situation statements. Each situation statement was designed to be mutually exclusive and was presented with situations increasing in sophistication. The DPM was structured with focus activities remaining grouped by core business function, flowing from business administration to production and resource management and then to marketing. Every participant saw the identical statement order; there was no randomisation of presentation order. Twelve validation questions were placed at the end of the DPM tool. Seven items required elements to be ranked and five asked about which datasets were already being combined for analysis. The objective of the questions was to quantify the importance individuals placed on different datasets and to compare this with answers in the DPM tool.

4.7.2.4 DPM Scoring

The DPM required the individual manager to select the statement that most closely matched their current situation (now) and the one to which they aspired (desired). These instructions were presented at the start of the tool (Appendix G). If they had already achieved the ‘desired’ level, the same statement would be selected for ‘now’ and ‘desired’. For example, for the focus activity business systems, the four options were:

1. There is a computer in the farm office but it is only used by Managers/Owners.
2. All members of the team have access to a computer/tablet or smartphone.
3. All team members have a computer/tablet or smartphone on which they enter data into the management system.
4. All team members have wearable technology, and all machines have some degree of automation.

All responses were downloaded for analysis. Each selection was recorded as ‘now’ or ‘desired’ by Qualtrics; these were converted to dichotomous scoring. Every selection received a score of ‘1’ and a non-selection, ‘0’. This gave a team with two respondents a maximum score of 88, and with three respondents, 132.

To establish stage of maturity the ‘now’ selections at each stage gate were summed for a Farm Business Team. The stage gate with the greatest number of selections indicated the maturity level. As the number of focus activities in the next maturity level increases, those in the previous maturity level decreased as they had already been attained.

The same process was applied to the ‘desired’ state to identify what level of digital maturity was desired. Selections were compared between members of the same business to assess consistency or divergence of opinions and objectives. Maturity was also assessed by core function or focus activity to identify areas of need and opportunity, especially in relation to interoperability of datasets.

4.8 Data Analysis and Validation

Approaches to data analysis and validity were related to the qualitative or quantitative nature of the data and the sample size. Thematic analysis was the primary form of qualitative data analysis applied across all data collection instruments. Descriptive statics were used to support the development of robust themes and to assess the evaluation scores. No further statistical analysis would be valid because of the small sample size and because the appropriateness of the score in relation to the individual’s perception was the matrix used to assess validity; hence validity is subjective at this stage. If the evaluation tools are taken to the next level of testing with a larger sample the design enables construct validity to be measured using exploratory and confirmatory factor analysis. Data analysis occurred at several stages of the sequential research (Figure 4.1), with modifications to the adoption framework made based on these findings. The following sections describe the data analysis and validation approaches used for the data collection instruments and the evaluation tools.

4.8.1 Surveys, Video Tutorials and Exit Interviews

Three data collection instruments were used to gather contextual data: beginning (surveys), middle (video tutorials) and final (exit interviews)—the latter from the team, the former two from individual team members. Multiple collection phases using open and closed questioning provided datasets that could be compared and contrasted using thematic analysis to produce rich descriptions.

If change is to be successfully achieved, all involved parties need to understand the reasons for the change and be aligned with the value of the change, as illustrated by the first two steps of the ADKAR. The team approach enabled consensus and divergence of facts (qualitative data) and opinions (qualitative data) to be identified and validated.

The three surveys by role provided the foundation data layer of quantitative and qualitative data. Quantitative data included facts about the farming system, the types of digital technology used and the uses of technology. Qualitative data from the surveys identified issues of personality and attitude to the use of digital technology. Qualtrics has an inbuilt expert review powered by iQ. This rated each survey design as fair, with failings relating to the high number of matrix tables that were required to identify types of technology used and wanted. Descriptive statistics were used to reveal patterns and themes from the surveys.

The video tutorials were both an information delivery and data collection instrument. The responses to the open questions built a detailed description of each

Farm Business Team's digital aspirations, concerns and approaches to implementation. The layering of team members' answers to each question provided an informative description of the process they wished to digitise first; why; who would lead the change; factors that prevented the change; and the datasets that would be required to support the digital aspects. Answers were analysed across and within teams. Responses to video tutorials were analysed using NVivo and used to produce word clouds to identify key words and topics (see Appendix I). These word clouds in turn were one resource used to inform the situation statements of the DPM.

Data from the surveys, which predominantly used closed question formats, were reinforced or clarified with statements from the video tutorials and semi-structured exit interviews. In addition, the exit interviews were used to verify the results from the evaluation tools. Exit interviews were used to capture changes in the team's attitude and application of DA during the 4-year research period. These recorded interviews also gathered the participants' attitudes and opinions regarding the appropriateness of the evaluation tools.

4.8.2 Commercial Interviews

Rankings of the six barriers to digital adoption were uploaded to Excel and all transcripts to NVivo 12 software, in which thematic coding was executed. An iterative, deductive, thematic coding approach was used to analyse the interview transcripts. Initial coding was based on the six barriers to adoption (Figure 4.5), with second-round coding based on subthemes from the first three steps of each half of the Change Guide. Codes were recorded and defined in a codebook produced by the researcher (see Appendix J). Codes were discussed with the supervisory team and small subset were cross checked by the team to assess appropriateness of definitions. Theme weightings were calculated from the NVivo and with the terms and language they were used to inform the task and situation statements in the evaluation tools.

4.8.3 Evaluation Tools

A combined qualitative and quantitative analysis aimed to demonstrate the appropriateness of the structure, content validity and scoring of each evaluation tool. Descriptive statics were used to assess the maturity scoring system of the DKSA and DPM evaluation tools, which were subjectively reviewed by participants. With larger samples statistical analysis would be used to quantify the internal consistency (repeatability) and construct validity (to check the phenomenon of interest is being measured) of each tool. With the small population sample used in this study, such techniques are not valid. Thus, at this stage, only content validity could be assessed. Schriesheim et al.(1993) stated that content validity exists when 'a measure is judged by one or more persons as containing a reasonable representative sample of items from the construct's theoretical domain' (as cited in Tiku & Pecht, 2010).

In this research, judgement was supported by data collected through the survey, semi-structured interviews and video tutorials to create the initial task and situation statements. The iterative Delphi method was used to refine the structure and population of the evaluation instruments. (Meijering et al., 2013; Okoli & Pawlowski, 2004). This iterative approach uses qualified experts—in the study context, the Farm Business Team members—to identify the most important issues of interest. This required multiple short bursts of interaction with, and data collection from, each team member, initially in response to the fifth video tutorial and then to the evaluation tools. Participants completed each evaluation tool and provided feedback that was reviewed and used to edit the evaluation instruments. The edited tool was then retested by the participants and the process repeated until consensus was achieved. Each tool contained validation questions with an associated score. An individual score for the tool was compared with the validation scores to assess content and score validity; the objective being that the tool score should closely reflect the validation score.

4.8.4 Credibility, Rigour and Trustworthiness

The research design and execution strove to achieve high standards of credibility, rigour and trustworthiness at all stages. The research question was developed from extensive exploration of the research married with the researcher's considerable industry experience. Recognised theories and approaches to research practice were the foundation of the design and the design was executed faithfully.

Participants were volunteers who chose to be involved with the research. A criteria for involvement was participants needed to be struggling to adopt digital agriculture, which automatically introduces some bias into the population, as did the need to have a trusted adviser. Both these criteria are anticipated to bias the participants to be more progressive farmers with larger properties (Bramley & Ouzman, 2019; Llewellyn, 2014). Invitations for involvement in the farm teams were distributed widely via credible farming networks in the agricultural sectors and regions of interest. Similar rigour was applied in the engagement of commercial companies, where the desire for a spread of types of digital provision, together with the inclusion and exclusion criteria, limited the number of appropriate providers with commercial operations in Australia.

All data were gathered directly from the participant using either electronic platforms such as Qualtrics or audio-visual recordings. All providers received an electronic copy of the transcribed interview. Each participant in a Farm Business Team received summary reports of their team's responses to the video tutorials and a Digital Knowhow Report. Managers were provided with a Digital Process Maturity Report.

4.8.5 Transferability and Dependability

The research was designed specifically to address the needs of digital adoption in Australian broadacre cropping and livestock production. Consequently, many of the task and situation statements used to populate the evaluation tools were specific to this target population. Similarly, the adoption issues and solutions expressed by the providers were specific to Australian agriculture, including the ranking of the adoption barriers.

It is considered that the Change Guide section of the adoption framework is transferable to agriculture in other parts of the globe, because it is based on diffusion of innovation and change management theories that are widely adopted by many industry sectors. The structure of the adoption framework, the stage gate definitions and scoring are likely to be appropriate for other agricultural sectors in Australia, but task and situation statements are considered to require modification to the sector in question.

The mixed methods approach based on a design consisting of multiple data collection instruments enabled data to be cross-referenced at multiple points in the research. This was supported by the juxta positioning of data collection from the teams and providers around the same six adoption barriers.

This thesis contains a detailed description of the processes used for data collection and analysis. These choices are supported by clear reasoning. Data are stored using FAIR data principles in the UNE's repository for research publications and research data (known as RUNE).

4.9 Summary of Chapter 4

This chapter has presented the arguments for the choice of method used in this research. It details the approaches used to implement a mixed methods approach and the sequential research design with a concurrent embedded element. Specific information about the three-part adoption framework, and iterative development and validation of the evaluation tools—which are central to the outcomes of this research—are described.

The research questions, logic for the selection of setting, participants, timeline and instruments for the data collection are detailed. An overview of the analytical methods used to interrogate the data to address the research questions is presented as are any ethical issues and how these were addressed. The methods described were applied to ensure credibility, trustworthiness and reliability in the data collected and to enable transferability and dependability of approach, including rigour in analysis and interpretation.

Chapters 5, 6, 7 and 8 address the results in relation to answering the main research question and each of the sub-questions. They are presented in chronological order in relation to the data collection timeline:

RQM: *How can an adoption framework improve uptake and use of digital agriculture by a family farming business?* (Chapter 8)

RQ1: *What are the fundamental components of digital agriculture for grain, livestock and mixed farming businesses?* (Chapter 5)

RQ2: *Why and how do farm businesses initiate the use of digital technologies for farm management and how could this be supported by a change management approach?* (Chapters 5 and 7)

RQ3: *How do commercial providers of digital agricultural hardware, software or support services, view and address the barriers to uptake of digital agriculture?* (Chapter 6)

Chapter 5: Results and Analysis—

Surveys and Exit Interviews

The results and analysis of this mixed methods research are presented in four chapters (5–8). In the current chapter, the information gathered via the surveys for the three roles of team participants is presented, together with statements reported in exit interviews that illustrate changes that occurred during the research period. These two sources primarily support answering sub-question RQ1: *What are the fundamental components of digital agriculture for grain, livestock and mixed farming businesses?* They also help address the first part of sub-question RQ2: *Why and how do farm businesses initiate the use of digital technologies for farm management?*

5.1 Fundamental Components of Digital Agriculture

The surveys provided a standardised and efficient way to collect data from remotely located teams specific to role. The information gathered enabled an understanding of the farming businesses and their current and anticipated use of DA. A completed survey was received from all 18 participants (100% completion rate). The results from the surveys were integrated with statements from semi-structured exit interviews that concurred with the survey data or illustrated where change had occurred during the research period.

5.1.1 Team Composition and Education

This research worked with five teams, composed of three roles. Each team had at least one Manager, one Operator and one Trusted Adviser (Figure 5.1). Three teams had four members, each with two Managers. These Managers were either a husband and wife, father and son, or siblings. All Managers were business owners and the majority reported equality between Managers in decision making, although two reported ‘I always have the final say’. In three teams the Operator was a direct family member; in one an in-law employee; and in another, purely an employee. Three of the Operators characterised themselves as farm workers and two as operational managers. During the exit interviews its was clarified that the operational manager in Team 3 had primary responsibility for the business administration.

Two teams (Teams 1 and 5) had Trusted Advisers that were also family members who operated commercial advisory businesses. Two Trusted Advisers were agronomists and farm business advisers (Teams 4 & 5), one an agronomist (Team 3), one a livestock specialist (Team 1) and the other a soil and technology specialist (Team 2). Three operated their own business and two were employees.

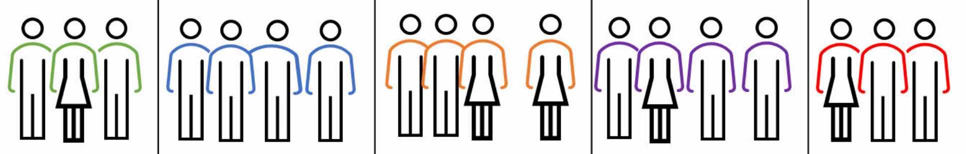
	Team 1			Team 2				Team 3				Team 4				Team 5		
																		
Role	M	O	A	M	Ma	O	A	M	Ma	O	A	M	Ma	O	A	M	A	O
Age (years)	51	52	22	36	34	32	30	28	57	57	41	42	42	19	47	60	62	32

Figure 5.1

Structure of the Farm Business Teams

Note. Role—Manager (M or Ma when two managers in a team), Operator (O) and Trusted Adviser (A). Touching figures represent family members and separated figures represent non-family member employees or contractors. Gender is identified by trousers—male, skirt—female.

In total there were 13 male and 5 female participants in the research, ranging in age from 19 to 62 years (Figure 5.1). Three of the five females had undergraduate degrees, two of which related to agriculture; one had a post-secondary qualification and the fifth did not complete Year 12. None of the male Managers had an undergraduate degree; two had post-secondary qualifications; three had completed

Year 12; and one had not completed year 12. Operators ranged in qualifications from not completing Year 12 to having an undergraduate degree related to agriculture. All Trusted Advisers had post-secondary qualifications, with four having undergraduate degrees relating to agriculture. This was the only case where an association between level of education and role was observed.

Where participants had not completed Year 12 or attended university, they often reported having other careers outside farming at some stage. These resulted in skills development in roles including builder, auto-electrician, secretary and registered nurse. It appears that some businesses valued formal education more highly than others, with all members of Teams 1 and 5 having completed post-secondary education or an undergraduate degree.

5.1.1.1 Stage in Career

Of the eight Managers, three reported to be in a growth phase with the objective to increase income to sustain their young family, and four were increasing income to support the succession of the next generation on to the farm and retirement of the current generation. One was starting out and gearing up, which requires capital for machinery investment. Three of the Operators were early in their career, one was 'cruising along' and the fifth winding down. Two of the Trusted Advisers were early in their career, two mid-career and increasing responsibility, and one in late career, increasing their mentoring. All but one participant over the age of 50 years considered themselves to be in their late career, but all Managers regardless of career stage were expanding income. It was noted that the two Managers in Team 4 who were the same age, responded differently to the question about their stage in their farming career. Both were expanding income, but one for young family, the other for succession. During the exit interviews these two Managers confirmed that at the start of the research they had just taken over the family farm, so they were expanding income for their own succession, rather than that of the next generation.

5.1.2 Farm and Business Structure

All teams farmed in South Australia using dryland farming systems. Farm size ranged among teams from just over 1,000 ha to 7,500 ha, divided across multiple blocks. The maximum distance for a block from the homestead ranged from 12 km to 60 km (Table 5.1). The type of farming enterprise and its dominance in the income stream influences the type of technologies used and their associated value proposition. All enterprises had some livestock. As a proportion of total income, this ranged in contribution from 10% from a small feedlot (Team 3) to 75% for prime lamb and wool enterprises (Team 1). Team 1 also generated approximately 5% of income from providing contract production services to other farmers. The remaining teams ran significant livestock enterprises, but their income was dominated by growing cereals either for grain or hay. Because of frost, which can prevent grain formation, Team 4 had pivoted from harvesting cereal crops for grain, and instead conserved them as hay and straw, so their income was dominated by forage crops. Team 3 was the only team that received a substantial portion of income (30%) from growing other non-cereal grain crops. In summary, the five teams derived their income from either grain production, hay and straw, or wool and meat production.

Table 5.1

Summary of Farming Business by Team

Team identifier	Production sector by value	Farm size (ha)	Number of blocks	Distance from homestead to furthest block (km)
Team 1	Mixed—livestock dominant (1,800 sheep)	1,166	5+	12
Team 2	Mixed—crop dominant (3,500 sheep)	7,500	5+	20
Team 3	Cropping plus small feedlot (100 cattle)	3,750	4	60
Team 4	Mixed—fodder-production dominant (1,200 sheep)	2,800	3	15
Team 5	Mixed—crop dominant (1,700 sheep)	3,350	5+	26

Note. Participants were only given the opportunity to provide details of four blocks and the home block, but state if more than five blocks were farmed.

5.1.3 Digital Technology Currently Used

Digital technologies can be very enterprise specific (e.g., on-animal technology) or have universal application, such as a mobile phone. Because of differences in enterprise mix, differences between teams and types of technologies used were anticipated. All roles received identical questions with digital technologies divided into three categories: hardware; connectivity; and software and data sources.

5.1.3.1 Hardware

Participants were asked to identify which hardware they used, did not have, did not use or want, had stopped using, were provided by a third party, or they wished to purchase. Twenty digital technologies were presented in one of two usage groups (Figure 5.2):

- management, communication and guidance
- cameras, sensors and measuring tools.

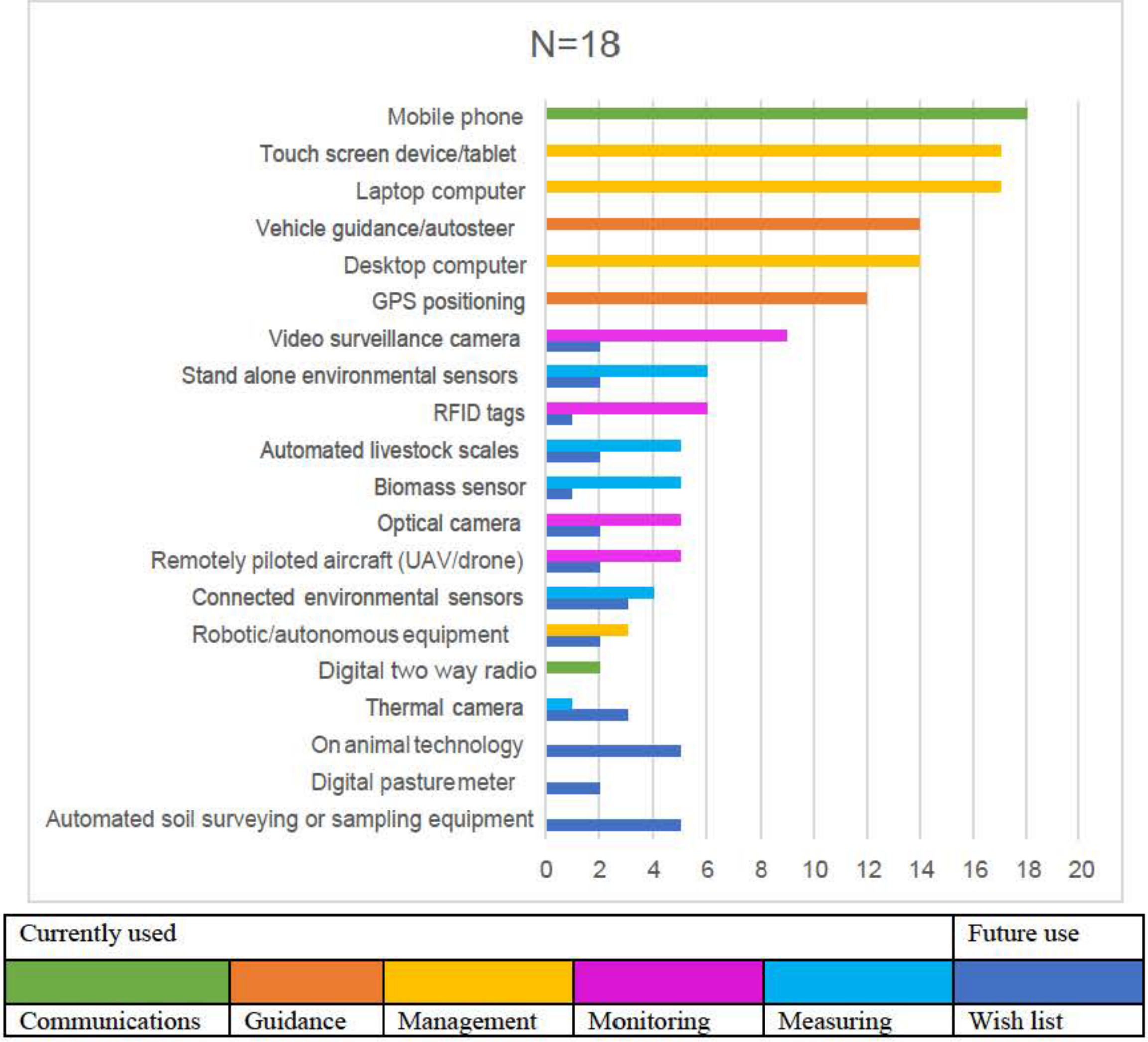


Figure 5.2

Technologies Currently Used or Wished for by All Participants

Note. One participant stated they used autosteer but did not select the enabling technology of GPS.

Of the 22 technologies, 43% were used by one or more participant; 44% were not used because they did not have or did not want the technology; 8% were reported to be wanted; and 3% provided by a third party. A mobile phone was the only digital technology universally used. All participants had access to at least one of the following: desktop computer, laptop computer or touch screen device/tablet. All farming businesses, except Team 1 that derived the majority of their income from livestock, had vehicle guidance and GPS—a set of tools more likely to be used by cropping businesses. The responses indicated that 73% of uses were of technology not specific to agriculture.

Managers used 45% of all the technology options offered; Operators, 41%; and Trusted Advisers, 39%. For this small sample size this difference is negligible but the lower use by Trusted Advisers might be explained by the fact that some technologies were located in farm machinery or were for business administration. Three technologies—automated soil surveying or sampling equipment, digital pasture metres and on-animal technology—were not used by any of the participants, but each was on the wish list of at least one participant (Figure 5.2).

Consistency in responses between team members was attributed to differences in knowledge, and in turn might be associated with role and associated technology requirements. Both these facts were confirmed during the exit interviews.

In the exit interviews, Teams initially reported that very little had changed in relation to their investments and use of digital technology between 2018 and 2021. Indeed, three teams reported they had pulled back from further investment in DA for the following reasons.

> Team 2: ‘I wanted to see what falls out of this project, and it’s a bit of a reflection that we were getting caught chasing shiny things, and trying to refine things before we had support processes and other things in place’.
>
> Team 4: ‘We are still using the things we were using before. If anything, we have become a bit time poor in initiating some of the things we did think we would change. That is probably the biggest challenge’.
>
> Team 5: ‘We have tried a few but the owners come and go. There is a real mismatch of companies trying to get into this marketplace. It does take a bit of sorting out and its quite time consuming, just to actually go through the process of which one’.

As the exit interviews continued, additional comments about digital changes made in the timeframe of the research were reported. Teams 2 and 3 reported investing in a grain protein monitor—a technology that would not have been identified by the options offered in the survey's wish list item. Both these teams also reported moving to more cloud-based systems, often with current software. Team 3 had upgraded its guidance software, but stated, 'This was just a clunky mess, and then we rolled back to the old program'. However, Team 3 should not be considered as negatively viewing technology as they saw the value when it worked. As clearly expressed in their exit interview, 'One thing we did this year was a trial with 10 other farmers on using digital delivery advice for Viterra [the grain handling, storage and marketing company], and it was absolutely brilliant'.

Understanding what technology is not used can be as important as knowing what is used. In the exit interviews, several teams shared comments about why they did not use some or more digital technology:

> Team 1: 'I still feel it's my lack of knowledge and ability to use. Often simple, little things I miss. A [team 1 trusted adviser] could have solved it'.
>
> Team 3: 'Sometimes we are already locked into a system, so why get a whole new system when we can just build on this one that we already know. So that takes a lot of our choices out. And you don't change systems because the cost is prohibitive'.
>
> Team 4: 'We have never had a yield monitor in a header that has ever worked. And never had anyone that can fix it. So never bothered. I lack interest. I just don't care for it'.
>
> Team 5: 'Our accounts program went in to slowdown, so then we had to switch to Xero, which is a big job. Then you don't have access to the data that

was on the previous program, as soon as you stop paying you don't have access to it'.

In the literature, farm size was the only agro-ecological factor consistently associated with greater use of technology (Bramley & Ouzman, 2019; Kernecker et al., 2020; Tey & Brindal, 2012). Because of the small sample size in this research, no such relationship between proportion of technologies used, and farm size or importance of grain income or other factors could be statistically tested.

5.1.3.2 Connectivity

Connectivity between technologies to enable data flows is central to digital transformation. A series of items was presented regarding the importance of telecommunications connectivity at work and how it affected uptake and use of digital technologies. A mobile phone was the primary form of digital technology used by all participants (Figure 5.2), yet mobile reception across the areas farmed by the businesses was often constrained (Table 5.2).

All teams farmed at multiple locations and mobile phone reception was requested for the home block and up to four other blocks of land. Despite this reliance on mobile phones for communication and internet access, when Managers were asked to report on mobile phone coverage across their property, only five (from three teams) of eight reported full coverage at the main homestead block and none reported full coverage across all remote blocks farmed (Table 5.2).

Table 5.2

Mobile Phone Coverage by Area at the Main Farm and Remote Land; Count of Mangers Reporting (n = 8)

	Main farm	Block 1	Block 2	Block 3	Block 4
Full coverage	5	1	1	2	1
More than 50% coverage	2	6	5	3	2
50% coverage	1	1	1	1	2
Less than 50% coverage	0	0	1	1	1

Note. Maximum number of blocks that could be reported was four plus the homestead.

All participants reported internet connectivity to be very or extremely important to their business, irrespective of role, with ability to access both in the office and 'on the move' being important (Figure 5.3). All participants accessed the internet using a mobile device, with 88% of participants having access to one additional access method, usually the NBN. Monthly mobile data use ranged from 1–5 Gb to >20 Gb.

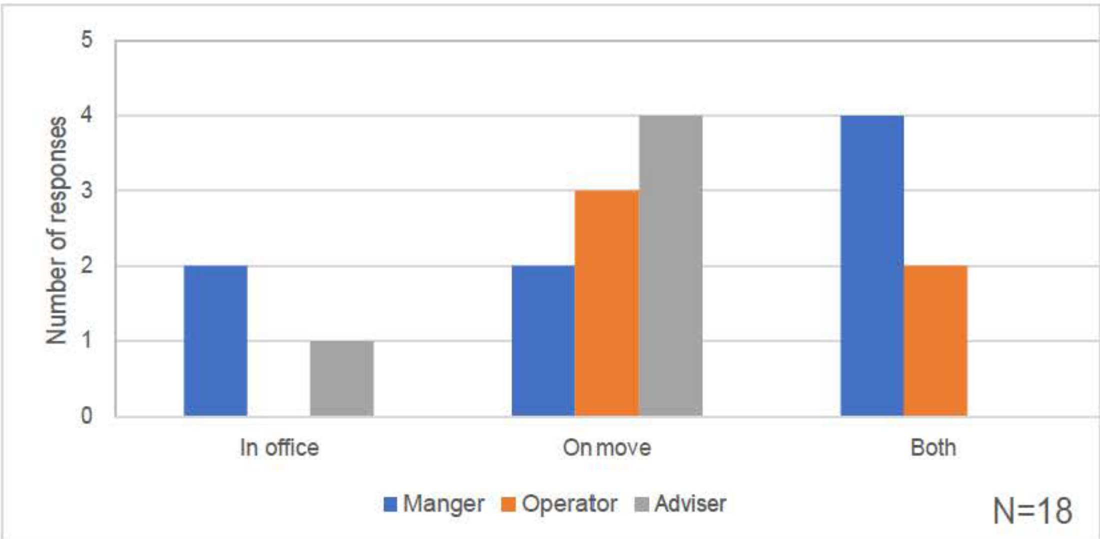


Figure 5.3

Most Important Location for use of the Internet by Role

Thirteen of the 18 participants reported a connection to the NBN. The Trusted Adviser in Teams 2, 3 and 4 reported having access to the NBN via fibre optic, the fastest connection option. Two teams had access to the NBN via a fixed wireless connection, which offered moderate data speeds and lower latency than the satellite connection used by Team 4 and the Operator in Team 2. Other members of Team 2 still relied on mobile and landline internet data services. The type of connection to the NBN was not a choice but specified by the service provider, the NBN Co., based on location to its infrastructure. Connection was generally only available as a single connection per location, so domestic and office requirements had to share a single data plan (Communications Alliance Pty Ltd, n.d). Specific uses for the internet were not requested but online video guides and online forums were positively received as useful ways for mastering a DA technology as reported later in Section 5.1.5.3.

Despite connectivity limitations being reported across most of the areas being farmed, there was no consensus from Managers and Trusted Advisers on whether lack of connectivity was the biggest barrier to them using more digital technologies (Figure 5.4).

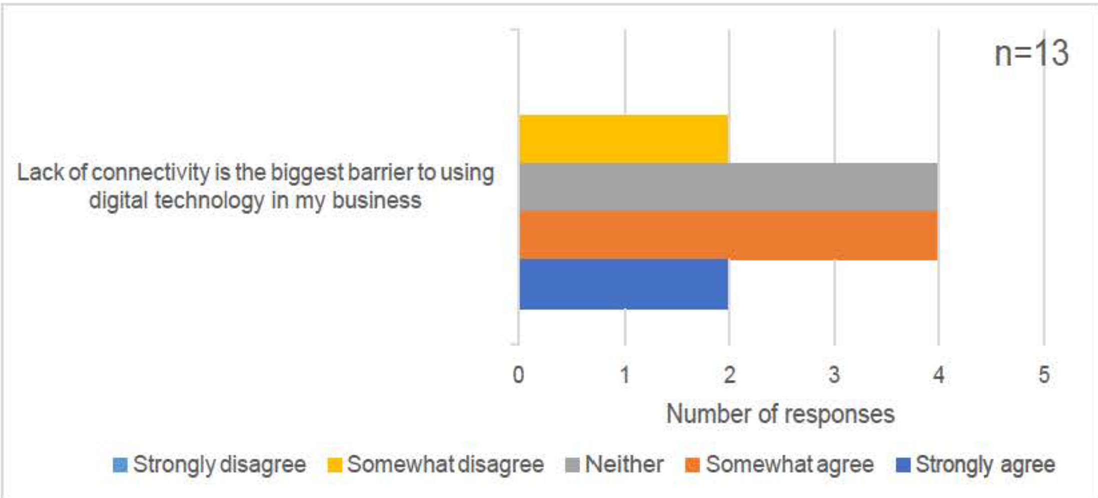


Figure 5.4

Attitude to Connectivity as a Barrier to Going Digital

When Operators were asked how they preferred to receive from and report information to Managers, 'face to face' was by far the preferred option and 'verbal methods' were preferred over 'written' (Table 5.3). Eight closed items were rated on a five-point Likert scale, where 1 = ‘like a great deal’, 2 = ‘satisfactory’, 3 = ‘neither like nor dislike’, 4 = ‘not keen’ and 5 = ‘dislike a great deal’. Participants were asked to score each item for their use in receiving and delivering information.

Table 5.3
Preferences for Receiving and Reporting Information, by Operator

	Receive					Report				
	1	2	3	4	5	1	2	3	4	5
Verbally—face to face	5					4	1			
Verbally by phone	2	3				3	1	1		
Verbally as a voice message		1	3	1			2	3		
Written on a whiteboard/notice board		3	2				3	2		
Written as a worksheet or in a book hard copy		4	1				3	2		
Written as text message	1	3	1				4	1		
Written and received as an email		2	2	1			2	3		
Written in a digital app/program that I access using my computer, smart phone or tablet		4	1				4	1		

5.1.3.3 Software and Data Sources

All team members reported on the types of software and other data sources used or wanted (Figure 5.5). The internet was the only universal data source used. Software usage was dominated by farm management and accounting software. Farm management and accounting software was reported to be used by 3/5 of Operators, all of whom were family members. In the exit interviews, one Operator identified their role was in business administration. The wish lists for additional software was very short.

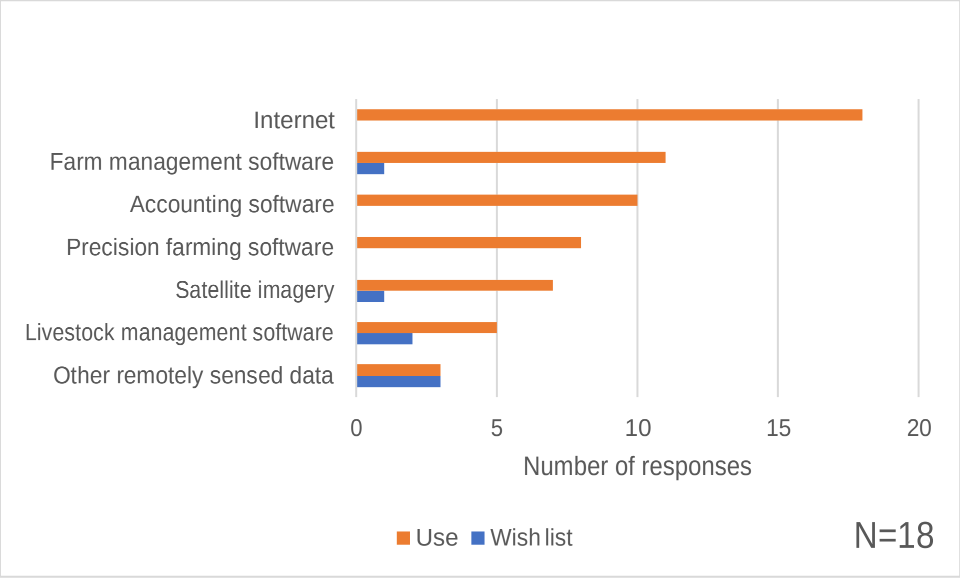


Figure 5.5

Software and Other Data Sources Used or Desired

Each team member was asked to identify the specific software packages they regularly used from a list of 21 proprietary products, or any others they wished to name. The software packages included those used for production management, precision/spatial management, machinery control and business administration. No more than five software packages were selected by any team, and all used at least three packages. Only Team 4 reported all team members accessing the same software. Of the 21 software packages, 11 were mentioned by a team member at least once. Teams 1 and 4 used their own software. Some of the unused options were brand-specific software such as John Deere APEX, which would only be relevant to owners of that brand. The crop production software Agworld was the most widely used, with 10 Managers, Operators and Trust Advisers from three teams reporting its use (Table 5.4). However, Team 5, based on the advice of their Trusted Adviser, actively chose not to use Agworld:

> Team 5: 'I have been an anti-Agworld person, because what happens is the big companies end up controlling your datasets. Eventually you get locked in, which really worries me. I know consultants that are into Agworld, and all of a

sudden they just put the price up, and they actually cannot afford to get out of it now because you put so much effort to get all your client data into a space, they are locked in and that is how they like to get you in'.

Table 5.4

Proprietary Farming Software Used, by Count of Team Responses

Software	Team 1 n = 3	Team 2 n = 4	Team 3 n = 4	Team 4 n = 4	Team 5 n = 3	TOTAL N = 18
Own*	1			1		2
Fairport PAM	2					2
Phoenix	1	3	2			6
Breedelite	1					1
AgriWebb		2				2
Agworld		3	3	4		10
Decipher		2			3	5
Production Wise					3	3
Agrisk		1				1
Trimble Ag Solutions			2	1	2	5
Agleader SMS			1			1
Farmworks					2	2
TOTAL selections by team	5	11	8	6	10	
% of 21 packages used	14%	24%	19%	14%	19%	

Note. * spreadsheets in Excel.

At the time of the survey, the financial management program Phoenix was the second most widely used, with six selections across three teams, followed by the spatial production program Decipher, and the machine control and monitoring system (including grain yield monitoring) Trimble Ag Solutions. Three years later at the exit interviews, teams reported that Decipher was no longer available and shared thoughts on this short-lived viability of digital tools:

Team 5: 'Too often they [technology companies] just think they have a good idea and they just push it into the marketplace and think that it's going to sell.

> Decipher is a classic. They even put on staff all over Australia and the basically end up hiving it off to CSBP [a chemical and fertiliser supply company]'.

In the exit interviews, Teams 3, 4 and 5 reported converting to the financial management package Xero. This package was not offered as a software option in the surveys and was not mentioned by any teams. The change to Xero from Phoenix was reported to be driven by accountants and the fact that for a period, Phoenix did not meet new payroll requirements initiated by the Australian Government. Participants who had used Phoenix were asked if they had considered upgrading:

> Team 3: 'We did. But they didn't have what we needed at the time, they didn't have the single touch payroll and our accountant recommended Xero. Which is good because they can go in and sort it for me'.
>
> Team 4: 'We started with Xero when we took over the business, and that is working really well for us and making our life easier. We are really happy with that as a program. And our accountant supports us a lot and can do that through the cloud, so we are loving that'.

The use of fewer software packages but more frequently was a preferred option. With frequent use participants reported becoming more confident in using the software and struggled when packages were used infrequently:

> Team 3: 'it is doing it and doing and doing it again. At the beginning of the season, I get all my contracts out and have a good think [about how I logged them in the software], and now [at the end of harvest] I am right, yeah bang. The value of repetition'.
>
> Team 3: 'that is what I find hard with SMS [software used for yield monitoring]. I pretty much had to relearn the program every year'.

In addition to the software packages, all team members were offered an open-ended item to list the online or application-based DSTs used (Table 5.5). Despite the plethora of agricultural apps and DSTs available, only 26 products were reported as being used, of which three were not specific to agriculture. In Table 5.5 these are categorised by focus activity, with FDI Calculator sitting between weather and production as it was used to make spray application decisions. The Willy Weather and Agworld apps were the only ones used by more than one team. Accessing market and weather information via mobile apps was the most popular use, along with accessing mobile versions of production software packages such as Agworld and AgriWebb.

Table 5.5

Mobile Apps and DSTs Used (N = 18)

Production	Weather	Spatial or location	Marketing	Other
Flyboss (1)	Weather Zone (3)	Decipher (1)	Pricemaker wool (1)	Car sales (1)
AgriWebb (1)	Willy Weather (5)	Measure map (1)	MLA livestock reports (1)	YouTube (1)
Agworld (3)	Climate (2)	Data Farming (1)	Grain pricing apps various (1)	Wunderlist (1)
GRDC Apps (2)	BOM (2)	360 Life (1)	Ezigrain (1)	
	Rain (1)	ASRIS (1)	Viterra (1)	
	Davis Weather (1)	Google Earth (1)	Australian Grain Export (1)	
FDI Calculator (2)			Centre State (1)	

Note. Number in brackets = number of mentions; ASRIS = Australian Soil Resource Information System, BOM = Bureau of Meteorology, FDI = Fire danger index, MLA = Meat and Livestock Australia.

5.1.4 Current Uses for Digital Technology

A series of items was posed to all participants regarding how they used digital technologies. Two approaches were taken; one being generic activities, the other specific task executed by cropping, livestock or mixed farming enterprises. In the generic items, half the activities were relevant to any business, and the others relevant to farming. In the more specific items, an understanding of the importance of digital technologies, not just the use of these technologies, was investigated.

5.1.4.1 Generic On-farm Uses for Digital Technologies

All team members were presented with the same list of activities and asked to select those they used. There were 10 uses and the option to specify others. Uses were generic or sector specific; for example, remote monitoring of livestock. With the exception of Team 3, all were mixed farming businesses, so could use all 10 options.

Table 5.6 presents the sum of responses by team, plus the total uses as a percentage (to place all scores onto the same scale) of the maximum total answers for a team. The option to specify additional packages was not taken up by any of the respondents.

Table 5.6

Use for Digital Technologies by Activity—Reported by Team

Activity	Team 1 n = 3	Team 2 n = 4	Team 3 n = 4	Team 4 n = 4	Team 5 n = 3	TOTAL n = 18
Communication	2	3	4	4	3	16
Collecting data	3	4	4	1	2	14
Entering and storing data	3	3	4	2	2	14
Sharing information	3	4	4	3	2	16
Analysis of data	3	2	1	1	2	9
Creating actions from data	2	2	2	1	2	9
Controlling machinery		2	2	3	2	9
Remotely monitoring machinery						
Controlling livestock	1					1
Remotely monitoring livestock	1	1			1	3
Other						
Total	18	21	21	15	16	
Use as a % of team	55%	48%	48%	34%	48%	

Communication and sharing information were the options most widely selected within and across teams. Analysis of data and creating actions from data were both less used than collection, entering and storing data, indicating data were collected but not necessarily used. No teams used technology for remotely monitoring livestock[1] or machinery. However, in responses to subsequent questions, remote access to machine settings and sensors was confirmed by Teams 2 and 3 (see Section 5.1.4.3). This suggests that the terms remote access and remote monitoring were interpreted in multiple ways and need careful use.

5.1.4.2 Uses by Task

Managers were asked to rank the importance of digital technologies for 15 specific farming and business activities (Figure 5.6). Trusted Advisers were presented with the same items but asked to respond in relation to how they perceived their use for the team in which they were embedded. Items were ranked by importance on a seven-point Likert scale, where 1 = 'extremely important', 2 = 'very important', 3 = 'moderately important', 4 = 'slightly important', 5 = 'not important', 6 = 'unsure' and 7 = 'not applicable'. Digital technologies for business administration and record keeping were ranked moderately important or higher by 13 respondents. This corresponded with responses to questions about software use where financial and farm management software had the greatest usage. As all farming businesses were dryland, irrigation was an irrelevant use; similarly, drainage is not a common activity on dryland farms. The use of digital technologies for the production activities of seeding, weed control and harvesting were rated very important or extremely important by 10, 9 and 8 respondents respectively. The livestock uses of breeding, feeding and pasture

[1] At the time of the survey, legislation in South Australia prevented the use of technologies such as the virtual fencing that enables remote control of livestock movement.

allocation had lower usage of digital technologies than did crop production. Other production activities showed a spread of responses. The use of digital for marketing was rated very or extremely important by seven respondents and moderately important by a further five.

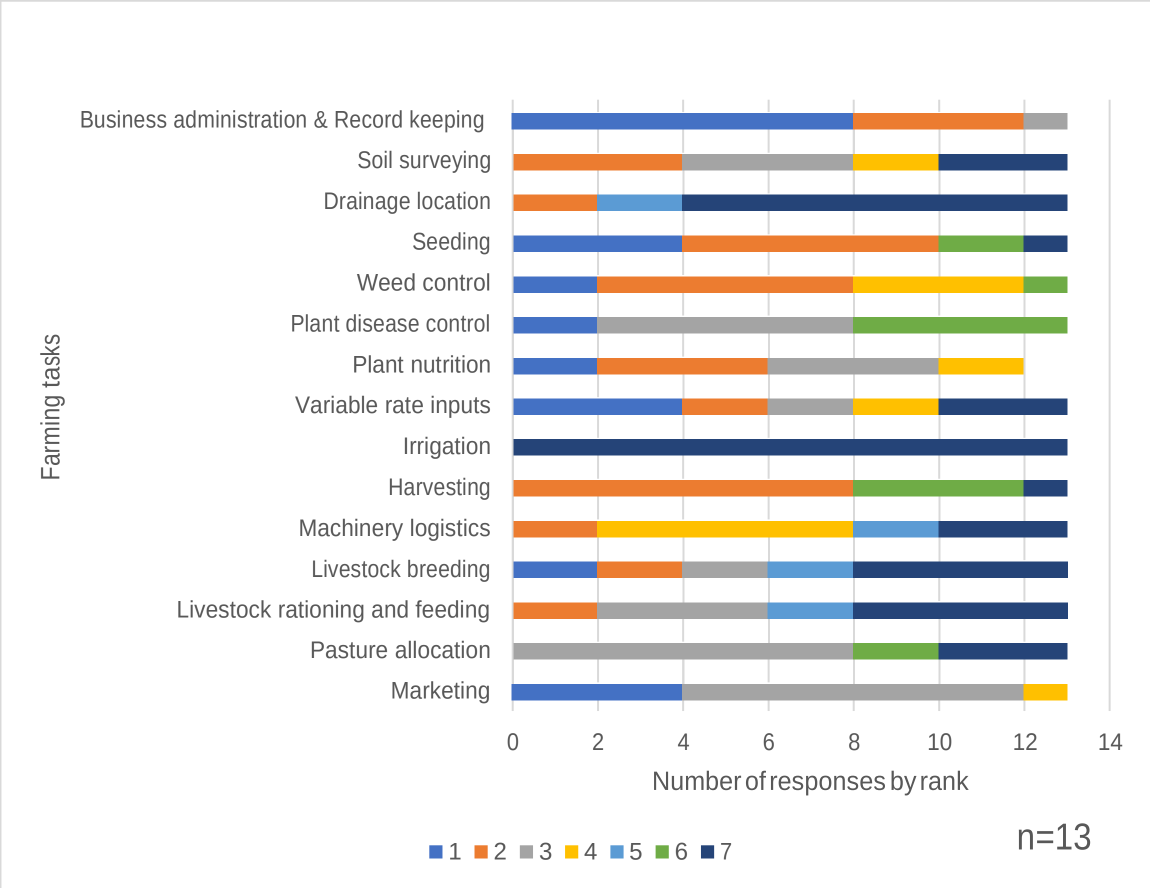


Figure 5.6

Importance of Digital Technologies for Specific Farming Activities, by Manager and Trusted Adviser Combined

5.1.4.3 Data Based Decisions and Data Sharing

Data collection, integration and use is central to digitalisation of process. All Managers said they were using single or multiple data types gathered by digital technology to make simple and complicated decisions. Of all the Managers, only one, that of Team 2, considered that Operators were making simple decisions based on digital data and no Managers considered that Operators were making complex decisions.

The same items regarding use of data for simple and complex decision making were posed to the Trusted Advisers about their clients in general, and the team in which they were embedded. Responses were based on a percentage of decisions made that were considered supported by data (Figure 5.7). The Trusted Adviser with Team 3 considered all decisions irrespective of client or complexity were supported by digital data. The Trusted Advisers of Teams 2 and 5 perceived that these teams, and their clients in general, relied more on digital data to inform complex decisions than simple decisions. In contrast, the Trusted Advisers of Teams 1 and 4 perceived that these teams, and their clients in general, made similar or fewer complex decisions with the support of digital data, than simple decisions. Teams 1–4 used more digital data than other clients of these advisers that were not involved in the research. The exception was Team 5, which used less data to support simple decisions than other teams or than their Trusted Adviser’s other clients. However, during the exit interview, Trusted Adviser 5 indicated that ‘rules of thumb’ or relative estimates, rather than specific data were used when making simple decisions on his own farm. For example, he indicated, ‘I suppose as you get more experience, a lot of stuff becomes second nature in the planning and organisation’.

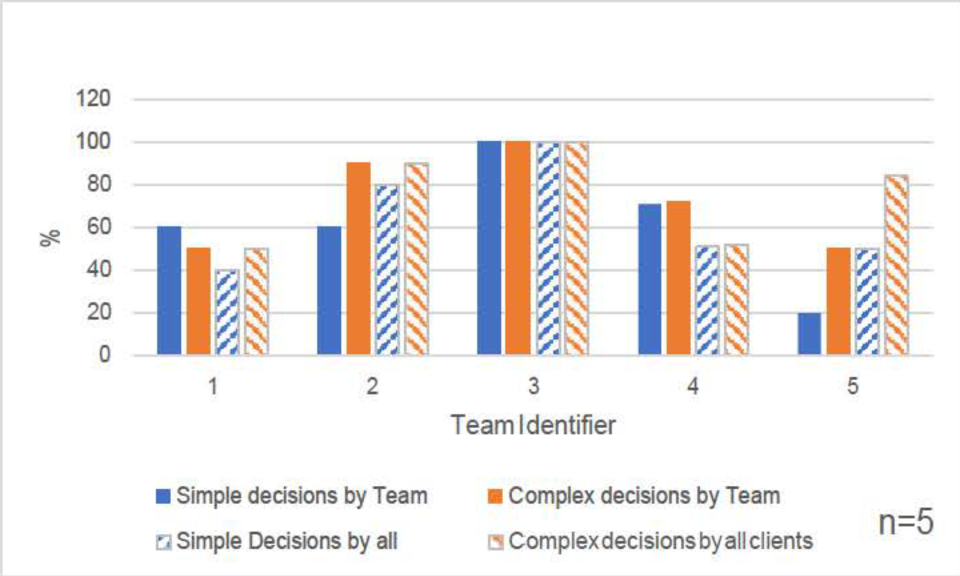


Figure 5.7

Trusted Advisers' Perceptions of Data Use for Decision Making, by Team and all Clients

Managers were asked to rate their level of comfort regarding sharing data with members of farming groups, third-party service providers, or other suppliers and purchasers (Figure 5.8). Five of the eight Managers were moderately or extremely comfortable sharing data with other farmers but only two had the same level of comfort when sharing with other suppliers and buyers. The attitude expressed by a member of Team 2 was not uncommon: 'Probably none of us are overly concerned over safety and security, I do think we have some safety and security and processes there, but pretty happy to share data'.

Managers were also asked if lack of trust regarding the use by a third party or loss of ongoing tenure of their data were reasons for not sharing data. Lack of trust was not considered an issue by any Managers. Some reported they had not needed to share data, whereas others stated they were only sharing with Trusted Advisers. The fact that the latter was occurring through a proprietary software product not owned or controlled by the Trusted Adviser was ignored by all teams except Team

Managers and Advisers reported only sometimes reading licence agreements and terms and conditions before signing up to use a software package or application. The following comments provide an overview of the views of participants in regard to reading software agreements and terms and conditions;

Team 2: ‘No, I guess I am a bit trusting and don’t have time’

Team 3: ‘No, because have to accept to use’

Team 4: ‘Sometimes, if I don’t know the app or it has not been recommended’.

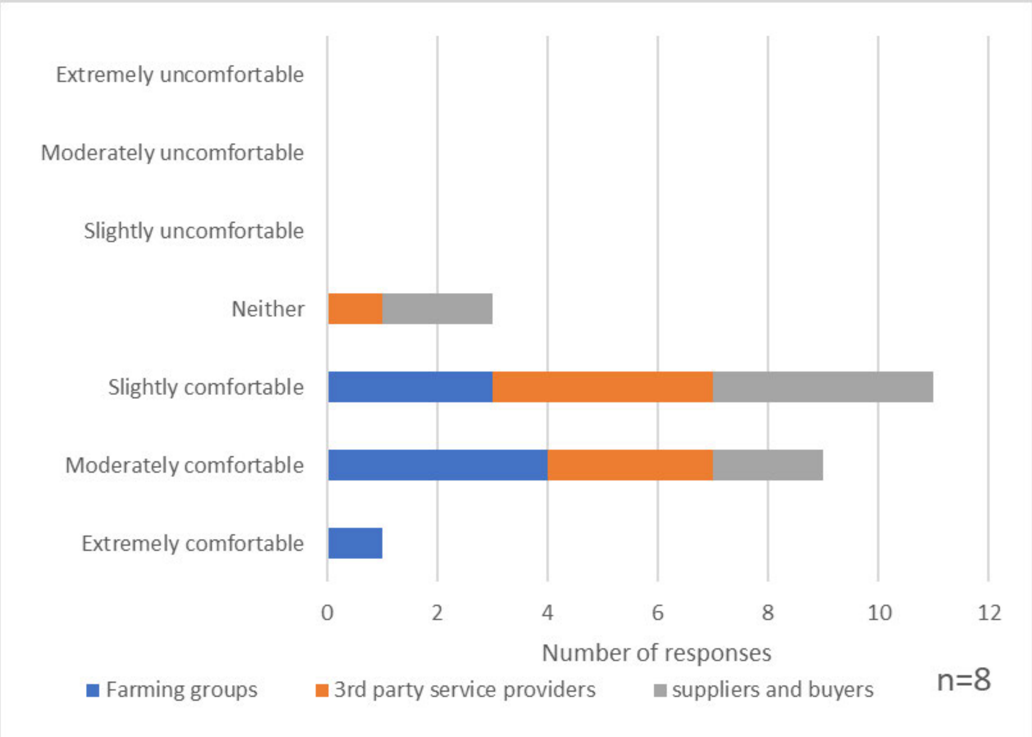


Figure 5.8

Managers’ Rating for Level of Comfort for Data Sharing with Different User Types

Data could be shared directly, via email for example, or by giving members of the team or others remote access. Managers were asked whether they gave remote access to data, machine settings or to sensors, ‘always’, ‘sometimes’ or ‘never’. All but two Managers gave remote access to data. Unlike the two that did not give access, all these Managers used the farm management package Agworld, which relied on data sharing between Manager and Trusted Adviser. Managers form Teams 2 and 3 were the only ones that gave remote access to machine settings or sensors.

The Trusted Advisers were asked whether they had access to data, machine settings and sensors in their nominated team as well as their clients in general. For the team and for their wider client base, the pattern of access mirrored that reported by Managers, with most Trusted Advisers having some access to data but little access to machine settings or sensors.

5.1.5 Perceptions of Digital Agriculture

To build a picture of the individuals and teams, the surveys included items relating to the participants' perceptions of digital technologies and their use in agriculture. These were divided into issues relating to the innovativeness of the adopter, their perception of the attributes of DA and the factors that might influence their adoption. These issues reflect Roger's Theory on Diffusion of Innovations (Rogers, 2003).

5.1.5.1 Innovativeness

The innovativeness of Managers and Trusted Advisers was assessed using responses to assertions seeking their attitude or opinion regarding DA. Operators were only asked to select the statement that they considered reflected their attitude to DA. Three Operators said they 'Like digital technology and try and learn how to use multiple functions'; one said they 'Like it but lacked confidence to learn new systems'; and the operator in Team 2 declared he was a 'digital technology junkie', using it wherever possible. The responses suggest a reasonable level of innovativeness, because of the generally positive attitudes to DA. When Operators were asked about their feelings about robotic tractors, the digital technology junkie was keen to learn new skills to work with robotic tractors, while the other four had no opinion and did not feel their job security was under threat from robots.

Managers and Advisers were asked to select statements that demonstrated why they used digital technology (Table 5.7). In total, the eight Managers selected 26 items, compared with 12 items for the five Trusted Advisers. The majority of Managers and Trusted Advisers used digital technologies because it improved efficiency and productivity, Managers were unanimous about digital uses for efficiency. One Trusted Adviser and none of the Managers selected statement 4, ‘the use of digital technology gives peace of mind’. Similarly, none of the Managers and only two Trusted Advisers selected statement 1, ‘I use technology wherever possible’.

Table 5.7

Reasons for Using Digital Technology—Managers (n = 8) and Trusted Advisers (TA) (n = 5)

		All	TA	Manager
1)	I like digital technology so I use it wherever possible in the business	2	2	0
2)	Digital technology improves the efficiency of my business	11	3	8
3)	I need to use digital technology in order to keep up with others in my industry	4	2	2
4)	I use digital technology because it gives me peace of mind when away from the farm	1	1	0
5)	Using digital technology will encourage the next generation to be involved with our farm	4	1	3
6)	I use digital technology because it improves productivity	10	3	7
7)	Using digital technology will help attract better employees	2	0	2
8)	Digital technology provides traceability along the value chain which my customers demand	4	0	4

Managers and Trusted Advisers were provided with the same seven items regarding their attitude to DA, with the option to indicate their agreement by selecting ‘yes’, ‘no’ or ‘unsure’ (Table 5.8). Responses indicated that Trusted Advisers were slightly more confident, and risked being inclined towards embracing additional technology, more so than Managers. Trusted Advisers were more likely to seek out technology solutions, where Managers indicated being influenced by others. Only one respondent, a Manager, indicated actively avoiding digital technology. There was only one response with 100% consensus: ‘I am keen to adopt when the technology solves a problem’. This solution-based attitude to change was reiterated in the exit interviews but availability of technology alone did not necessarily make it a solution:

> Team 3: ‘I guess we make changes out of need. It has got to make a dollar return or make our life easier’.

Table 5.8

Attitudes to Digital Agriculture—Managers (M) (n = 8) and Trusted Advisers (TA) (n = 5)

	Yes		No		Not sure	
	M	TA	M	TA	M	TA
1) I like to try new digital technology as soon as it’s available	1	3	5	1	2	1
2) I wait until digital technology has been proved to be useful by others	4	2	1	2	3	1
3) I tend to use digital technologies only when there is a need identified by others	2		2	4	4	1
4) I am keen to adopt new technology when it solves a specific problem	8	5				
5) I avoid using digital technology	1		7	5		
6) Overall digital technology helps my business, but it can waste a lot of my time	6	3	1	2	1	
7) I only use digital technology that is easy to install and learn	3	1	3	3	2	1

Note. Numbers highlighted in grey indicate a frequency of >50%.

Nine of the 13 respondents reported concerns over new technology wasting time; six of these were Managers. The need for time and the use of time to become a competent user were themes that were reiterated in the exit interviews as illustrated by Team 1 when referring to learning how to use the new digitalised weight scales and drafting system: ‘It is a learning process, have to persist because I could have done it manually in half the time with the old crate’. Similarly, a Team 3 member commented about the use of new digital equipment needing time: ‘Ours was a new header this year, 2020, so has telematics. I should have done more. I made an account and then I got stuck and it was 10 pm at night, and I have left it’.

Another member of Team 3 commented: ‘I have come to the conclusion that it’s me, it must be me that is the problem. I am getting sick of it because it takes me five minutes to log into this bank’s internet banking’.

The importance of factors that were perceived to help or hinder the adoption of digital technologies and approaches is reported in Table 5.9 to Table 5.11. Each factor was ranked on a seven-point Likert scale, where 1 = ‘strongly agree’, 2 = ‘agree’, 3 = ‘somewhat agree’, 4 = ‘neither agree or disagree’, 5 = ‘somewhat disagree’, 6 = ‘disagree’, 7 = ‘strongly disagree’. Responses to statements about use of digital technology were generally in agreement across respondents, even the negative statements. An example is statement 1 in Table 5.9, where the majority of Managers agreed that systems for agriculture data were lacking. Consistency of agreement was greater from Managers than from Trusted Advisers. Statements 2 and 3 were positive and had higher frequency of agreement from Managers than statements 1 and 4. Trusted Advisers had a wider spread of agreement for all four statements. The majority of Managers and Trusted Advisers agreed they only wanted to enter data once (Table 5.9, statement 4) but one Trusted Adviser strongly disagreed and noted that multiple software would be required for different tasks These ratings indicated a positive attitude to the use of DA but concerns over whether current technologies were fit for purpose.

As shown in Table 5.10, statements 1 and 2 were negative and both had a wide spread of ranking, irrespective of role. The majority of responses to statement 2 were neutral or disagreed with the statement that buying digital technology is difficult because of a lack of clear value propositions. Statement 3 was positive with all responses agreeing, most strongly agreeing. A range of rankings was given for statement 4—the need to establish a cost benefit—with the majority requiring this, but not strongly.

Table 5.9

Agreement Ranking for Statements Relating to Using Digital Agriculture

Role	Manager (n = 8)							Trusted Adviser (n = 5)						
Ranking	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1) The systems required to analyse, interpret and create actions from agricultural data are currently lacking.	1	3	2	2				2		1	2			
2) Digital technology enables more in-depth information to be gathered.	5	2	1					2	1	2				
3) Digital technology enables information to be analysed more easily.	4	2	1	1				2	2	1				
4) I only want to input data once not every time I use a different software package.	3	4	1					1	2	1		1		

Note. Numbers highlighted in grey indicate a frequency of 50% or greater.

Table 5.10

Agreement Ranking for Statements Relating to Perceived Value of Digital Agriculture

Role	Manager (n = 8)							Trusted Adviser (n = 5)						
Ranking	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1) The digital technology I have used is not sufficiently developed to meet my needs.	1	1	2	3		1		1	1	1		1	1	
2) Buying digital technology is hard to justify because there are few clearly demonstrated value propositions.		2	1	2	2	1			1	1			3	
3) Digital technology helps make my business more profitable.	3	4	1					1	2	2				
4) Before I buy new digital technology I have to be able to establish a cost benefit for my business.		4	1	3					1	3				1

Note. Numbers highlighted in grey indicate a frequency of 50% or greater.

The first four statements regarding digital literacy and support were negative; the last two were positive (Table 5.11). Response ratings to all statements were similar for Managers and Trusted Advisers, except for statement 2; Trusted Advisers were more willing to spend time learning new systems. The greater reliance on support (statement 1) and lack of support (statement 5) were seen as a challenge by both Managers and Trusted Advisers. Confusion over what to buy (statement 3) had a higher agreement by Managers but also had strong agreement from two Trusted Advisers. The majority of positive responses by both roles to statement 6 again reinforces a positive attitude to digital technologies but that the barrier of lack of digital literacy persisted. This was reflected in the exit interviews, for example Team 1 reported, ‘We are putting in a Wi-Fi network across the farm … for water and hopefully eventually virtual fencing and sheep tracking. It’s hard when you are an early adopter, you have to learn on the go’.

Across all the ranking statements, the Managers showed agreement or strong agreement with the benefits of digital for providing ways to improve efficiency, productivity and profitability through in-depth data collection and analysis. They reported stronger agreement regarding the lack of on-farm support for digital technology and that purchasing was confusing, than regarding the lack of clear value propositions or need to establish a cost benefit before purchasing. The Trusted Advisers generally showed a greater spread of rankings than the Managers, were generally less risk averse, and willing to learn new systems. However, like Managers, they saw digital systems making their businesses more reliant on external parties to keep them operating. Statement 4 in Table 5.10 was the only one universally agreed on: ‘adoption is driven by the need to solve a specific problem’.

5.1.5.2 Perceptions of Technology Attributes

Perceived attributes of a technology include users' opinions of the relative advantage its adoption brings, which include financial benefits; complexity and compatibility with current technology; and training and trials. Managers and Trusted Advisers were asked to rank five perceived attributes of DA. Attributes were scored on a five-point Likert scale for influence on the decision to adopt; from very strong, strong, neither, weak, or no influence. Each attribute was considered by at least one participant to have a strong influence (Figure 5.9). Ease of use was the most influential attribute, with 8 of 13 respondents nominating it as a very strong influence.

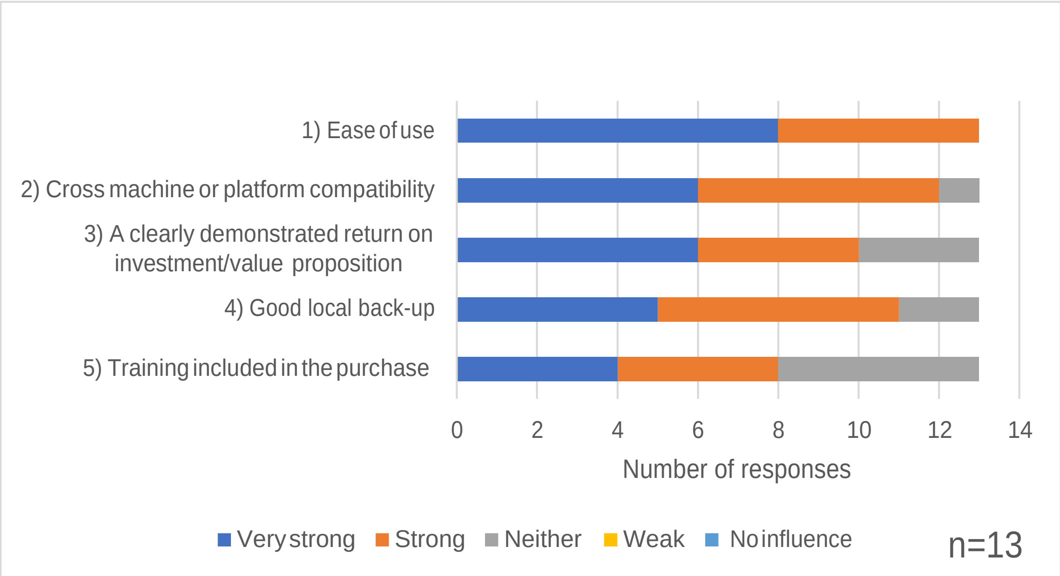


Figure 5.9

Factors Influencing the Uptake of New Technology, by Managers and Trusted Advisers

There was an equal weighting for cross-machine or platform compatibility and a clearly demonstrated return on investment. Good local backup and the inclusion of training in the purchase came in fourth and fifth when only considering very strong influence. If very strong and strong responses are combined, a clearly stated value proposition fell from equal second most important to fourth for the items reported in Figure 5.9.

Several items investigated perceptions of value proposition and the formation of purchasing decisions. Responses to the survey items indicated that the purchase of digital technology was ad hoc and to solve a particular problem (rather than strategic). When Managers were asked about digital investment strategies and budgets, their selections were inconsistent between items and between Managers from the same team. Teams 2, 3 and 4 each had two Managers; yet in response to the item, only one of the two reported having a strategy for DA. The remaining five Managers answered 'no'. None of the Managers reported having a budget for investing in DA, although when asked if they had a budget and how much it would be, all Managers in Teams 2, 3 and 4 selected between $500 and $25,000 per annum. The main reasons stated for not having a separate budget were that the price of the digital technology was included in the price of the machine and because investment for digital was allocated in other areas; for example, business equipment or capital items. This lack of strategy could also be linked to lack of perceived value, as expressed in the exit interviews:

> Team 4: 'I am not against digital, but I guess I need to see the value in it, and I don't see the value in it at the moment or I see the value in some things but not in everything. I like Xero, yeah its great and really easy'.

Only the Managers were asked for more detailed information regarding the required return on investment on digital technologies based on direct and indirect financial benefits. The responses showed a wide range of opinions and potentially the difficulty Managers had in relation to expectations from going digital. This was supported by the ranking of statement 3 in Table 5.11 regarding digital being confusing because of so many options. Over half the Managers required higher returns for technologies that saved time or improved productivity, than for those that improved security or gave peace of mind (Figure 5.10). This appears contradictory but may be because Managers answered based on anticipated rather than required return.

Table 5.11

Agreement Ranking for Statements Relating to Digital Literacy and Support

Role	Manager (n = 8)							Trusted Adviser (n = 5)						
Ranking	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1) Digital technology makes my business more reliant on external parties to keep it operating.		1	6	1				1	3		1			
2) I avoid updating digital technology because learning new systems takes time.	1	1	3	2		1			2			1	1	1
3) Buying digital technology is confusing because there are so many options.	2	2	3	1				2		2	1			
4) There is a lack of support to make digital technologies work on farm.	1	5	1	1				2		2			1	
5) I regularly update our digital technology as I like to keep up to date.		2	2	3	1			1	4					
6) With more training I would use more digital technology.	2	2	3	1				1	3			1		

Note. Numbers highlighted in grey indicate a frequency of 50% or greater.

Managers and Trusted Advisers were provided with the same items regarding the amount of time and money they were prepared to invest to install and learn to operate digital technology, which had no clear financial return. Two Managers said they would not invest unless there was a clear financial return; three Managers were only prepared to spend less than $1,000 on digital purchases without proven value propositions; two, between $1,000 to $5,000; and one stated over $15, 000. The latter response may have been influenced by a recent digital investment of over $30, 000 that had failed:

Team 3: 'It stopped us from spraying, multiple times in a day, because it kept crashing, not loading paddocks, not loading AB lines [the reference line for a paddock] and then just randomly stopped because it felt like it. It was disgusting'.

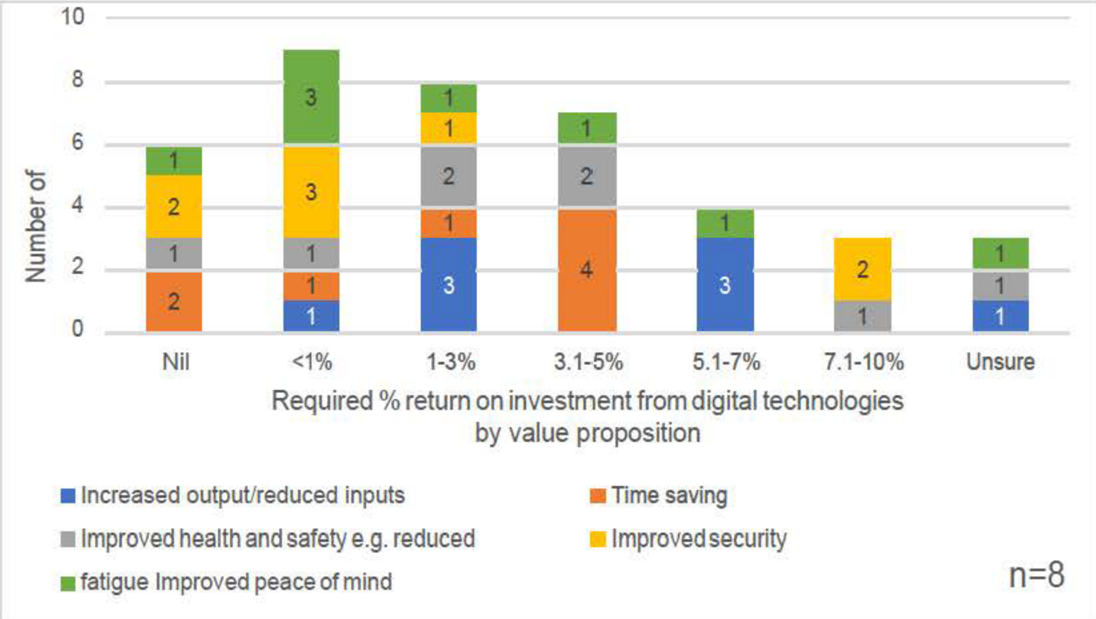


Figure 5.10

Required Return on Investment from Digital by Value Proposition Reported by Managers

Note. Percentage return over a 3-year period.

Six of the eight Managers would allocate less than 1 day to install and learn such equipment. One would allocate zero time, while another would give 'as long as it takes'. When responding to the same items, the Trusted Advisers were prepared to spend on average $5,000 on an item with no proven financial return and up to a week setting up and learning how to use such a digital technology. The attitudes to cost and value of digital technology were captured in the exit interviews:

Team 2: 'The cameras are only about …, I did look into FarmBot, but they are quite expensive, they are about $1,200 for one sensor, then you had to do a yearly subscription on top of that. So, these you buy as a one off and you can do a solar add on to them so you would never have to recharge them'.

Team 4: 'But it's the cost, if we don't have the time to put the effort into using it properly, we are probably not willing to spend the exorbitant fees on it at the moment'.

When an open question was asked about what was preventing Managers investing in digital solutions, responses included the following with the number in brackets representing the number of mentions:

- lack of training and support (3)
- issues of platform integration (2)
- too many apps/options and lack of time to investigate (2)
- cost (2)
- lack of expert information (2)
- in transition—machinery and labour (2)
- lack of knowledge (2)
- internet connection—quality and coverage (1)
- unreliable mobile service (1).

5.1.5.3 The Influence of Support and Backup

In this section factors that might have influenced digital technology adoption, over and above the innovativeness of the Farm Business Team and their perception of the technology's attributes are reported. Managers and Trusted Advisers were asked about the strength of influence of five items on their purchases of digital technologies (Figure 5.11). All five were considered to have some degree of influence, although statements 3 and 5 were both considered weak influences for one participant. A direct recommendation from a user they knew (statement 1) had the greatest influence.

Enthusiasm from a member of 'your business and product reviews' rated second and third most influential. For 7 of the 13 participants their gut feeling had a strong or very strong influence on their purchase decision. This exemplifies the concept of acting like a consumer rather than a corporate purchaser (Kaine et al., 2011).

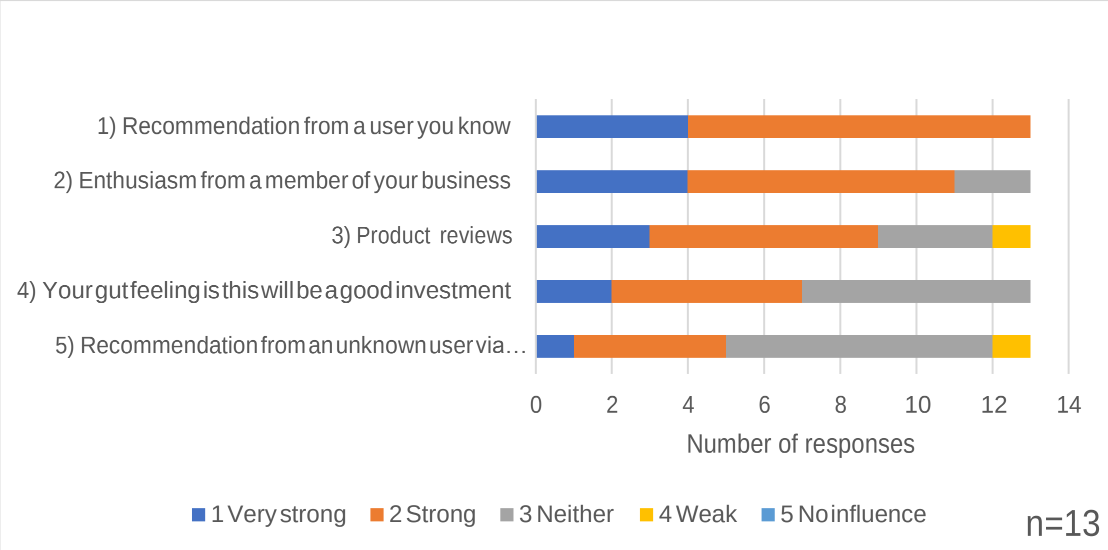


Figure 5.11

Strength of Influence on the Purchase of Digital Technologies, by Managers and Advisers

The need for support and backup has already been captured in Table 5.11, and is supported by the responses in Figure 5.12, with specialists in DA being rated as the most useful for technical support. One statement from Team 3 illustrates the conflicting tension regarding lacking time and skills to set up a digital technology and not wanting to pay for specialist support:

> We need someone with experience, and cost is going to be the killer. But, for a reasonable amount of money, you need be able to say—I am going to use X software, to collect yield and protein data and want to make them into replacement maps and be told what you need to buy, what is compatible with what. That would be useful. But he is going to charge you $5,000 to do it, so you are just going to do it yourself. I guess the other one is, I feel I should be

able to do it and I don't want to pay anyone to do it. But if I haven't got the time, I am not going to pay someone to do it.

The preference for different sources of information was anticipated to be influenced by learning style, local availability of specialists and skills within the team. When it came to mastering a digital technology, Managers and Trusted Advisers rated the support from a local dealer lower than the assistance received from other family members or colleagues, from other farmers, and from specialists in DA (Figure 5.12). Indeed, one respondent suggested local dealers were 'useless'.

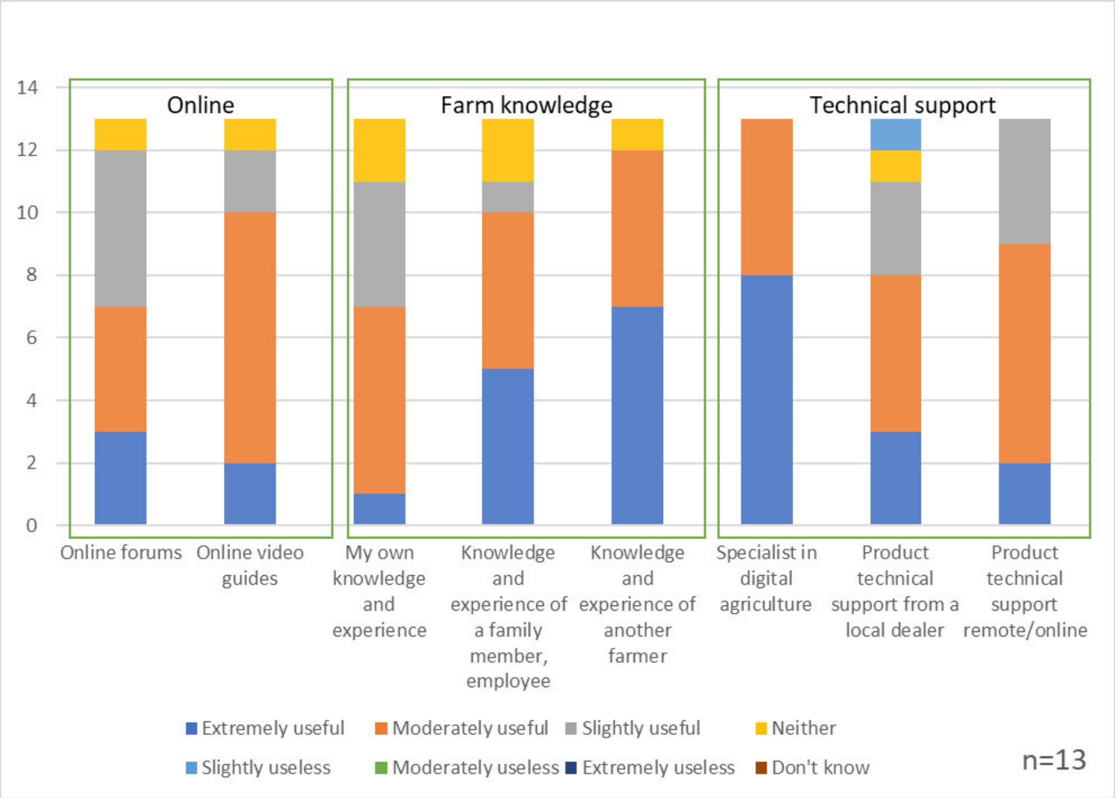


Figure 5.12

The Usefulness of Different Information Sources for Improving Digital Literacy— Managers and Advisers

The responses in Figure 5.12 were not specifically related to a time period; that is, pre- or post-purchase. In the exit interviews, the importance of training and online support was commented on by a member of Team 4; however, these resources did not cement the purchase of the software although they did ensure its use:

Team 4: 'I have done a little bit of training with that [Xero], and I guess the rest of the programs I don't care for because there is no training. I don't feel like there is any training or any help, so I don't care for them and just get frustrated when I cannot do something simple'.

5.2 Summary Chapter 5

The survey and exit interviews provided key insights into Managers', Operators' and Trusted Advisers' engagement with digital technology. Despite the small research sample of five teams comprised of 18 members, the participants provided a diverse range of demographic combinations, knowledge, experience and potential digital technology applications. The use of the team approach was fundamental to this research design and findings as it highlighted different perceptions and aspirations of team members and even differences in the reporting of farm and enterprise details.

Clearly, adoption will occur if a technology offers a solution to a problem being experienced. With support, even reluctant adopters used technology if it met a need, suggesting moderate to high innovativeness in the Farm Business Team members. Data were said to be used to support complex and simple decisions by most Managers and Trusted Advisers, but rarely by Operators.

Mobile phones and the internet were the most widely used technologies. All participants also had access to a desk, laptop computer or touch screen device. Business administration and communication were the most common uses. In addition, digital tools were considered important for marketing and vehicle guidance. Despite the high use of mobile devices for communication and internet access, none reported full mobile coverage across all parts of their farming businesses. However, there was ambivalence expressed with regard to this being a major barrier to the uptake of digital technology.

Lack of time to select and learn new technologies, and products being short lived in the market, as well as becoming locked into a technology and having to re-enter the same data more than once, were issues that could impede adoption. The frequent use of just a few software packages was popular because of the value of repetition. The need and lack of capable support was also reported as a limitation to using more digital systems.

When participants were asked directly, they expressed an expectation for digital technologies to provide a financial return, yet indirectly, responses indicated that technologies that improved efficiency and security were popular. Cost, regular subscriptions and the fact they felt they should be able to be self-sufficient and not paying others to select and set up technology were associated with perceptions about value proposition.

Overall, responses supported the supposition that investment in digital technology is ad hoc and rather unplanned. Farming businesses lacked digital investment strategies and budgets, and items on their wish lists were inconsistent between team members.

The surveys and supporting comments from the exit interviews provided a rich and detailed description of the farming business and the people in the business team. The survey data provided a strong foundation for the research and initiated the engagement process between the researcher, the teams and the research. However, the closed nature of the questions restricted the free flow of ideas, which was addressed using the open question format applied in the data collection via the video tutorials (Chapter 7). The following chapter presents the results from the semi-structured interviews with providers of digital solutions for agriculture.

Chapter 6: Results and Analysis—

Commercial Providers Interviews

The providers of digital technology play an important role in the technological and sociological factors influencing digital adoption. This chapter reports on the findings from semi-structured interviews with the providers of digital agricultural hardware, software and services. It is concerned with commercial perceptions of the barriers to adoption of DA and how these providers promote adoption of DA. Results in this chapter specifically address RQ3: *How do commercial providers of digital agricultural hardware, software or support services, view and address the barriers to uptake of digital agriculture?*

The following results and analysis stem from the transcripts of the 18 hours of recorded interviews with 14 Commercial Providers. The objective of these interviews was to better understand the commercial perspective on the barriers to adoption of DA and how the providers considered these were being addressed by their business. With this understanding, a new perspective on these adoption barriers was presented.

6.1 Barrier Ranking

Because of the range of digital products and services provided across the 14 commercial companies interviewed, consistency in the rating of barriers was not anticipated. All providers agreed that these six items continued to present barriers to the adoption of DA. Figure 6.1 illustrates that three clear grouping emerged when the six barriers were ranked by influence: value proposition and digital literacy were generally considered the most influential barrier; availability of data and decision support tools (DST) a moderately influential barrier; and trust and legal issues and connectivity a small barrier to adoption. When these results were aggregated according to the barriers nominated as the top three, 79% nominated value proposition; 64%, available and appropriate datasets; and 64%, digital literacy, indicating these were the top three barriers to adoption from the perspective of the providers interviewed (Figure 6.2). The importance of demonstrating value if digital technology adoption is to occur on farm, was frequently raised in all interviews. This was reflected in the fact that 67% of references were initially coded to the value proposition node in relation to products and services delivering value or purchasers and users perceiving value (Figure 6.3).

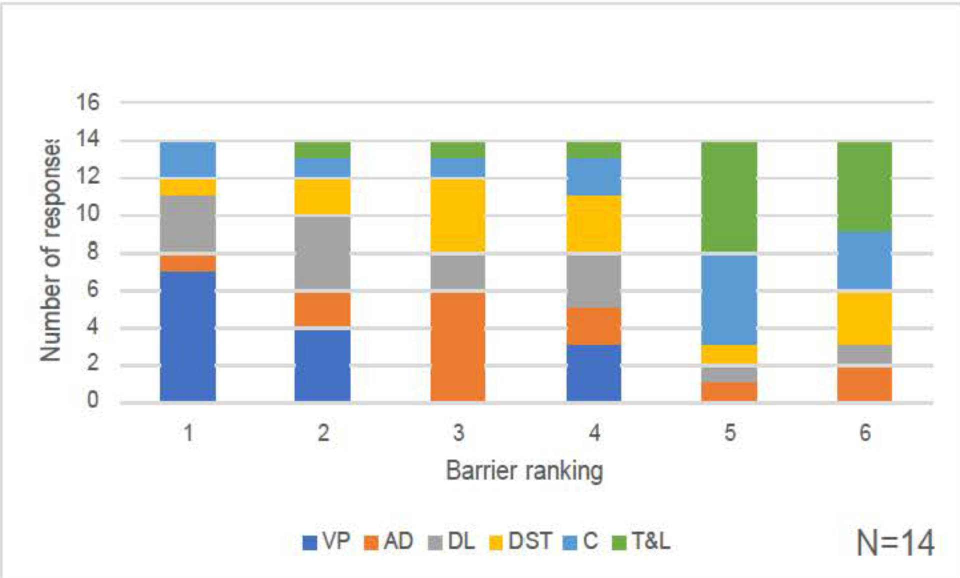


Figure 6.1

Barrier Ranking from Strongest, 1 to Weakest, 6

Note. VP = value proposition, AD = available data, DL = digital literacy, DST = decision support tools, C = connectivity, T&L = trust and legal.

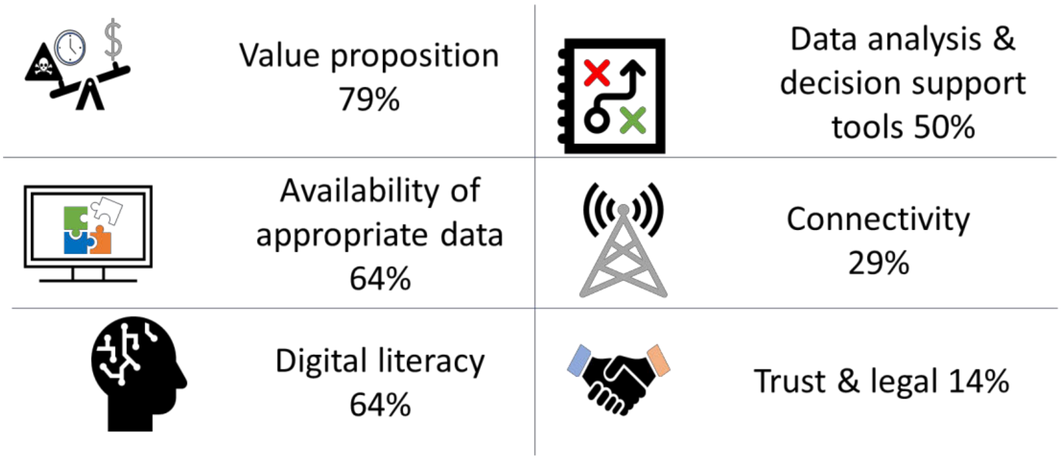


Figure 6.2

Rankings for Barriers to Adoption of DA, by Percentage of Responses in Top Three

6.2 Reference and Word Analysis

Multiple rounds of thematic coding were executed. Themes were defined in a codebook that evolved during the second and third rounds of coding (Appendix J). Transcripts were coded manually by the researcher. The initial thematic codes were the six barriers to adoption outlined in the P2D summary report (Leonard et al., 2017) (also provided in Appendix L), with statements relating to value proposition divided into those that provided value to the supplier and those to the user

6.2.1 Initial Coding

The first round of coding to the six themes resulted in a total of 803 statements coded, with 67% relating to value proposition (Figure 6.3). Coding for statements relating to the other five barriers was roughly evenly spread, with 8% for data availability; 7% for both trust and legal, and connectivity; 6% for digital literacy; and 5% relating to decision support and analysis. No differentiation was made between the allocation of positive and negative statements. Where statements contained multiple sentiments, they were allocated to more than one code.

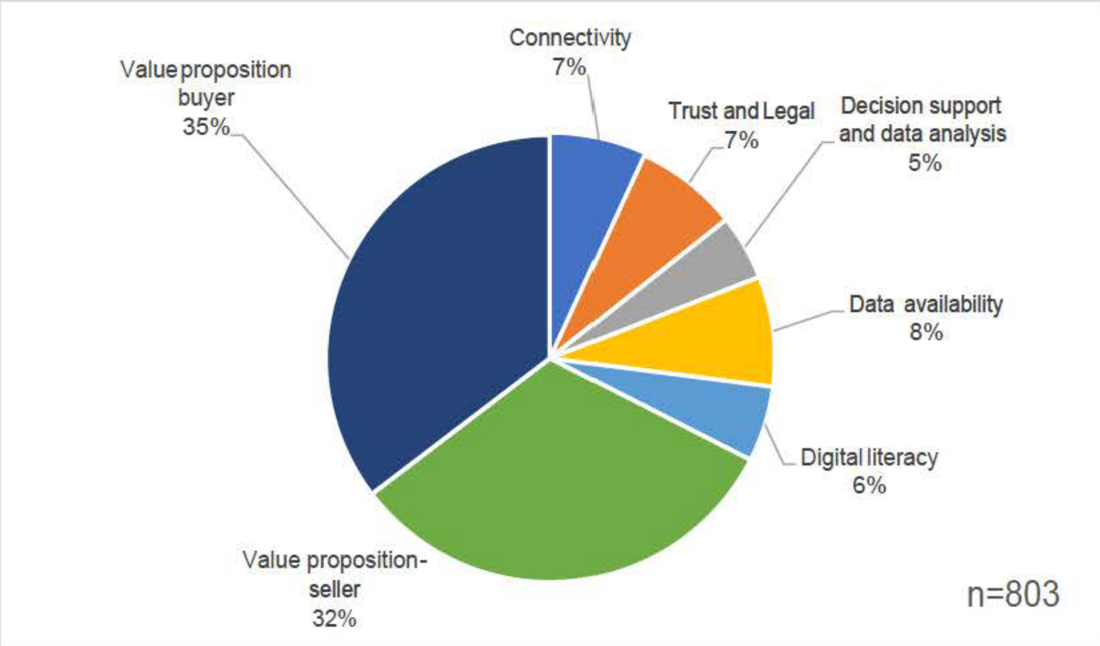


Figure 6.3

References Coded to the Six Adoption Barriers—First-round Coding

6.2.2 Secondary Coding

To gain further insights into the value proposition, additional subcodes were considered. The second-round subthemes related to aspects of the DA adoption framework designed as part of this research (Figure 4.2). While the framework was established to support farming businesses in their adoption of digital technology, the two theories supporting the framework offered a structure by which the emotional and pragmatic aspects of barriers to adoption could also be assessed from a provider's point of view.

For each barrier, up to six subcodes were added, relating to the first three steps of each side of the framework: awareness, desire, knowledge, need, success and evaluation (Table 6.1). The first three items related to ADKAR change management and were considered from the perspective of how the suppliers were working to overcome the barriers. The last three related to the innovation decision and were aligned to the providers' views of the users' digital aspirations, and perceptions of the impediments.

The framework is bound by three factors known to affect adoption, two of which, time and influencers, emerged as themes during the first round of coding, with communication as a subcode. Reallocating text using the more expansive codes and subcodes revealed greater clarity of the factors contributing to creating a value proposition. Two additional themes evolved during the second-round coding: ecosystem and individuality. Definitions for the new codes were added to the codebook (Appendix J).

Table 6.1

Subcodes from DA Adoption Framework and Code Definition

Innovation decision	Definition	ADKAR	Definition
Knowledge—identify need	User's view of need(s)	Awareness—why change	Provider illustrates, demonstrates commercial offering
Persuasion—define success	What is the desired/required outcome (user and/or provider)	Desire—what's in it for me	Provider shares, explains benefits, advantages for the user
Decision—evaluate options	User determination of relative advantage	Knowledge—how and what to change	Support to make the change to a new product or service

Use of the six subcodes and four additional primary codes resulted in 896 references at one or more code (Figure 6.4). Despite all interviews being structured around the six barriers, statements from each provider were not allocated to every code, with digital literacy, and trust and legal, having statements coded from only 12 of the 14 providers. At the subcode level, value proposition awareness and value proposition need were the only subcodes to have statements from all 14 providers. The subcode data analysis—knowledge had the lowest number of statements per code, and from only four providers. Value proposition, digital literacy and data availability returned the greatest number of statements coded with the proportion of statements coded to the six barriers in the second round now closely aligned with the top three rankings from the providers interviewed (Figure 6.2 and Figure 6.4). The exception was data analysis, which had fallen from fourth to sixth by the number of statements coded to theme. In the second-round coding, value proposition remained the barrier with the greatest number of statements, despite the second-round coding allocating many value proposition statements to the themes contributing to the value. For example, 'aftersales training and support adds value but through digital literacy' was coded to digital literacy. Over one-quarter of all statements related to the new codes: influencers and communication; ecosystem; time; and individuality (Figure 6.4).

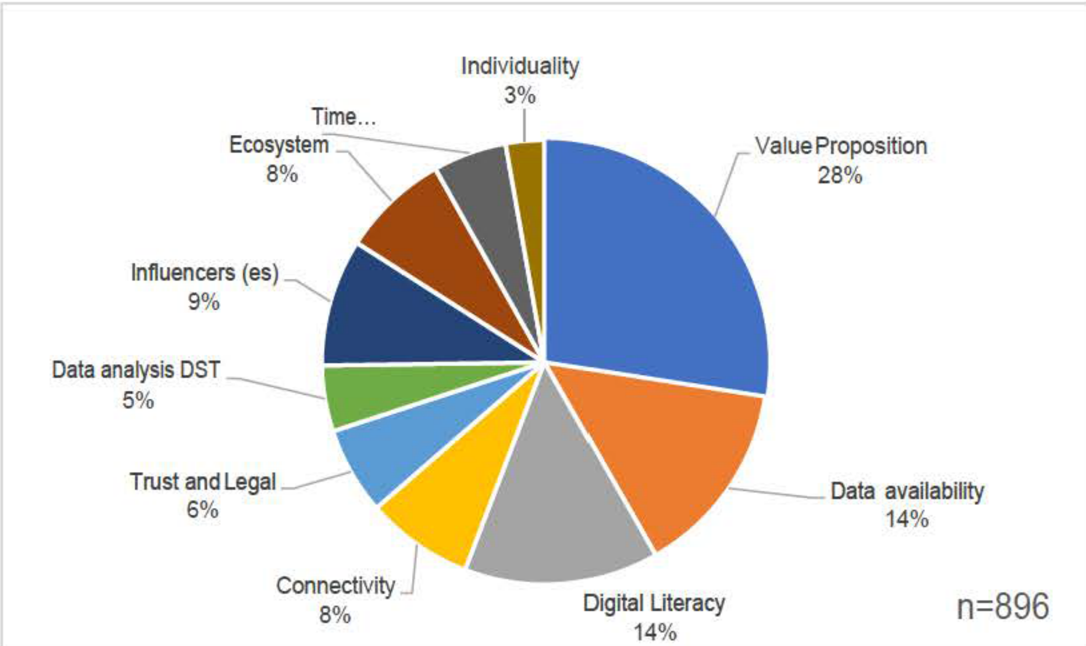


Figure 6.4

Percentage of Total Statements Coded by Theme—Second-Round Coding

Statements often contained multiple sentiments and were coded to two or more subcodes. To streamline the analysis, the following details are reported against the primary codes in the order of codes with the most to least supporting statements.

6.2.3 Value Proposition

The value proposition of DA includes tangible financial benefits and less tangible advantages of saving time, reducing fatigue or reducing risk. Value was considered by the providers as central to achieving adoption: 'I do think that farmers are really good at adopting new technology, providing the value is there'. However, value is tightly entwined with users' personal perceptions, goals and priorities. Consequently, there are many established systems and incumbent systems that can impede the adoption of new technology. As two interviewees stated:

> Farmers have existed for generations, very successfully without digital data. They don't need digital data to be successful and make money to meet their goals in their individual farming system.

> One of the barriers is the fact that technology is turning up where it's not completely new, in some part its displacing existing. Pen and paper, and spreadsheets are still the biggest barrier to adoption.

Changing to a new solution takes confidence because an element of risk in facing the unknown is introduced. Consequently, high demands are placed on the new technology, often higher than on the incumbent solution that would be displaced: 'You have to be 10 times better to overcome the inertia of adoption'. Several interviewees mentioned the need for users to perceive the new solutions to be 10 times better than the current process with which they were familiar. Some felt that this need to demonstrate such a high level of benefit could result in overselling:

> They get comfortable with that, they take ownership and emotional attachment to that piece … to transition to another system, they don't want to give up that comfort zone.

> What happens is that users often overestimate the value of that [current] solution by about three times. What it does and its capabilities are over

> estimated. Then you have new solutions that come through based on smart phones or IoT or cloud based solutions and they have a certain feature set, and they are often over sold by three—the reality is you often over promise, or the temptation is to over promise because you have to displace an existing solution.

Experienced suppliers reported that farmers were 'primarily motivated by cost reduction' and that value must achieve more than just financial returns. This need for more than a dollar return may be linked to the fact that a quantitative benefit can be difficult to prove in agriculture because 'there are so many things that cloud the picture'. Providers found that once the initial adoption hurdle was overcome, the technology cost became a smaller part of the value proposition: 'The ones that do it are just sold on the idea; they can genuinely see how they are doing but their measures aren't monetary'.

If technology provides intangible benefits such as convenience, compliance and capacity, as well as financial benefits from risk avoidance, adoption is more likely to occur. One provider reported customers stating these benefits from using their software: 'It gives me access all the time; it gives me efficiencies in terms of time saving; I can be paperless'. If the digital application is too complex or too focussed on the technology rather than the solution provided, then adoption is unlikely: 'We have to get our reality aligned with what we are trying to do. And simplify the value down into simple chunks that people can digest and build on'. Other statements that supported this belief included, 'If you start at one level that is easy and cheap and you pick up a few easy wins and at least it helps you begin the conversation to go into a little bit more detail'.

The suppliers often reported the dilemma of choosing between providing simple solutions and expensive end-to-end solutions: 'Once you start users getting that value, the cost becomes inconsequential, because the value proposition becomes so high'. Providers reported that technologies that add cost had a negative perception and an even greater need for clear, relevant descriptions of the value they could provide: 'Our system is expensive I guess and a lot of them see it as just a weather station and not the analytics and the data that comes with that'. Providers also reported that once they had overcome the initial adoption hurdle, the technology cost became a smaller part of the value proposition: 'The biggest barriers are lack of perceived value of using the system and the actual cost, it is quite expensive when you start adding up all the different systems that are out there'; and 'Even if it's a subscription to the services they need to see what that benefit will be and how it will benefit them before they will take that leap'.

A long-term provider of DA technology noted that providers had been their own worst enemy when communicating issues of value: 'We have created the illusion that digital is cheap, its actually not. Simply adding a button can cost you $40,000 by the time you have designed it, develop it, QA it, release it'. Conversely, as prices of technology have reduced, potential purchasers could still have the perception that they were overly expensive, as described by one hardware provider: 'The farmer took a stab at what our display was worth, and he was out by double what it was worth' [if the display cost $10,000 the farmer had guessed the cost to be $20,000].

The value proposition was recognised to differ between corporate and family farming businesses. For the former it was driven by marginal improvements: 'they [corporate farms] have said that small gains in efficiency for them equals big dollars, so they can see the value': and for the latter, by personal values: 'but the absolute value was $40,000 or $50,000 of annualised benefit from conducting the work and his response was, "ah it's hardly worth it really, is it?"'. Such statements reinforced the fact that purchases by family farming businesses were influenced by personal values:

> They [farmers] look at software through a consumer lens, and they think of it like you would a consumer product. So, farmers will look at our software and our average plan will cost $125/month and will be like 'that is ridiculous, why is it so expensive, software should be free, Google is free'.

The suppliers acknowledged it was their responsibility to create, demonstrate and deliver value, but they also found it hard to articulate that value. Indeed, 6 of the 14 interviewees made at least one statement about lack of clarity around the value proposition, including comments suggesting individuals had to find their own benefits. The first three comments in the following list relate to delivering value; and the remainder to the problems of lack of clarity around the value proposition of changing to digital:

1. To me, lack of value proposition, that's on the companies, that's on the people building tech, certainly not on the farmers.
2. You have to see their pain points and understand their pain points so you can solve [them].
3. We're a business that has to sell a product for a return, but we cannot do that unless we are delivering value to users in ways that are actually beneficial.
4. The key reason is that the industry as a whole has not been able to articulate the value proposition for the grower.
5. We have not yet explained to the industry and all the stakeholders what the base value outcomes are.
6. There are massive value propositions, but people are not yet aware of them or have not found them.
7. It's just not clear what the farmer is going to make out of going through all of this change, particularly going away from where they are now from just using planning and recording platforms and going to that next step.

8. That requires a business process to be applied and business recognition that there is value to find, but you just have to commit to finding it and that's a problem.

Until suppliers can articulate meaningful value to farming businesses, adoption will be limited to enthusiasts. Yet, without a critical mass of users, the viability of products and their further development for Australian needs is limited. Some providers recognised that, in part, critical mass of users would be achieved only by having less choice in the market: 'Critical mass means you have got less solutions dealing with more people and that's what we need to get in this space'. This issue was especially relevant to the small size of the Australian market: 'This market in Australia has been small, dysfunctional in a digital form. Until we make it more scalable then none of these things can deliver'.

In Section 6.2.9 dealing with trust and legal issues, the value of data sharing is further explored. However, it is along the value chain that some of the immediate benefits of on-farm digitisation may precipitate. Value, as well as data, needs to flow along the value chain. If value from data is captured only at points in the value chain that are remote from the point of capital investment in data capture, interest in such an investment is unlikely. Several providers promoted that on-farm data capture had greater value to those outside the farm business than to the farm business that is the source of the data.

> Data is not just valuable at the farm, it's got value at one level but who its really valuable to, its value is in transparency to serve the consumer.
>
> As an agronomist, I can deal with more customers because I have all their information in a digital context. I can refer to that. So, it's about time saving and ease of use.

If I can forecast demand for those products in a more targeted way, I can manage my capital inventory costs more efficiently.

6.2.4 Data Availability

Data are at the heart of DA: 'Without any data you have nothing' but 'it does not matter how good the data is, if they cannot use it and they don't understand it, there is no point'. Having the appropriate data was seen as everything, 'Because what happens once you start to get data, you get data overload. So, it's that you get too much data and it's the paralysis of analysis, so its understanding what are the right layers'. What is 'right' can be very user specific.

In the P2D summary report, data availability referred to the need for access to, and interoperability between stored data. During the commercial interviews, themes of data capture, quantity and quality also emerged. These were in addition to those of integration and making data accessible, useful and useable, although only one interviewee referred to the FAIR data principles: 'If you record it in a digital context its structured, its visible, reportable, findable; then the disputes are much less and not about hearsay but about fact'.

The main competitor for digital data collection was considered handwritten data. This is because it is easy to use and compatible, but providers recognised that digital has the potential to offer more: 'A piece of software can do a whole lot more than a piece of paper. Its maybe not as versatile but it's certainly a lot more proactive'. Despite software offering greater versatility than written data, these tools often required data to be manually uploaded, especially in the initial phases and this was seen as an adoption barrier: 'We have got data capture solutions where you can create interfaces that replace pen and paper, but you actually have to put information in them in quantity over time to start realising some of the value of those things'. Data capture was identified as a problem by several providers; for example, 'The problem is we have made it all to hard'. Part of the difficultly of digital data capture was considered the different formats and collection platforms required:

> We need to capture it once as an enterprise, digitising the farm enterprise and then make that reusable for as many other purposes you want.
>
> Right now, the problem in the industry is that we have farmers capturing maybe farm records in a non-spatial environment, anything from handwritten notes to whatever it might be. Then they will have some precision ag data which is geospatial in, then they probably have their farm financials in Excel or MYOB [accounting software] or some other non-spatial or nonrelated system.

How much data are already collected and what is required, was a subtheme that developed, particularly in relation to raising awareness of why change is needed. Lack of data related not only to on-farm data but also to larger national datasets. These points are illustrated by the following comments:

> I think the other big one is the lack of foundation data.
>
> Some people have not recorded anything for years. It's getting better now but we have a massive problem with not enough data.
>
> Lack of datasets and that's because people don't value the data to start with, which they don't.
>
> Probably 95% have not recorded what went where, what they yielded, not even the basic information. Yield data is terrible. We have guys saying they have 10 years of yield and when we look at it only about 3 of the 10 years of data are collected properly.

Others were more positive about the availability of data but considered its use the factor that was lacking:

> We have some core datasets available to us that we have had for 25 years, that we haven't even extracted value from yet.
>
> There is tonnes of value in just capturing the core data about your field and having an intuitive understanding of it.
>
> The data is there but it is how we can manipulate that and get it back to the grower. It is probably tools not the data itself.

The quality, rather than quantity and availability of data was discussed from several angles. Two suppliers of environmental sensors emphasised that maintaining the quality of the data they supplied was critical. Most comments regarding data quality related to data capture by the user and why capturing quality data can be difficult, as illustrated by these statements:

> We keep thinking we have a lot of data in ag but it's a load of crap, we have bugger all data, good-quality data.
>
> One of the big pain points of our products is that at the end of the day we're an app. So, we are only as good at the data that comes in and some of that data can be onerous to enter manually.
>
> There is data and there is data, unless the farmer is properly trained in setup and calibration.

While some of these comments suggest a degree of frustration, many providers did recognise that they needed to provide the solutions, not expect the users to adapt: 'We have to have the right tools to start with so people find it easy to collect the information'. In part the solution was seen to be through 'providing standardised data that is presented in an intuitive manner' and improving systems that were viewed as 'cumbersome and difficult [referring to file management]'.

Issues such as file management and inconsistency of data entry influenced the value and useability of data: 'Put in the right information, you get out the right data'.

Greater automation in data collection and management were considered opportunities to improve quality and timeliness of delivery as demonstrated by the following comments:

> The more we can automate the more we can bring in weather station data, and rainfall gauge data or bring in satellite imaging and actually have it give us something useful.
>
> We are automating all the things we used to do manually, in simple terms, and making it [data] more accessible to everyone.
>
> Delivery times are coming in within a few hours of capture. We used to have to download the images in raw format, time spent processing it, clipping it to field boundaries, exporting as PDF files and sending it to the grower. So would have taken 2 weeks, now they are getting it within 2 hours. We aren't touching up, its automatic.

Quality data require validation and ground truthing; tasks that providers perceived as unpopular with farmers: 'That is another problem, they don't do any trials. It would be easy to embed trials. But no one really thinks about doing it'. This lack of attention to detail when dealing with analysis was seen to limit the value farmers placed on available digital solutions. As one provider explained regarding on-farm trials, 'They cannot remember where they did their trial or they don't put trials in they just have a go, so then they have no baseline null hypothesis to measure it by'.

Several people commented on the industry's infatuation with perfection rather than precision. This had made data collection and use complex and unappealing:

> We have made it all too hard. We have created this thing but it's hard work.
>
> We don't need precision ag, we need slightly more accurate ag.
>
> Why are we using 95% confidence when we are talking about something that the weather is a hell of lot less than that. Yes, we want some accuracy and

repeatability and statistical validity but 95% is for engineering and medical science not for agriculture.

New solutions were being implemented to enable multiple data sources to be viewed and multiple people to have access to these data. Indeed, this bringing together of data and data users was seen as fundamental to the creation of value and subsequent adoption of DA. One provider summarised this need, 'What technology should really do is ultimately bring disparate sources of information together for multiple purposes for multiple parties that have an interest in a subset of that information'.

Where systems such as ISOBUS have supported 'plug and play' hardware options between machinery, interoperability and sharing of APIs was relatively immature at the time of the interviews. Relationships between machinery and data platforms were evolving and the following quotes indicate that providers viewed this evolution as an area of opportunity to support adoption:

> The idea is that you can begin to add value by being able to bring together different or disparate data layers together into a common solution.
>
> Data sits in many places in many formats and the challenge is getting them in a context or format that is actually achieving what I have recently become aware of as FAIR data.
>
> I suggest they start to understand how solutions can connect together and that's very much on us to build solutions and architectures that allow interoperability.
>
> Once you have created that global standard you can roll that information across the joint users.

The balance between data need and want, and systems to support their collection and use is summed up in the statement below. It illustrates there is a tipping point at which farms become so large and complex that the introduction of systems for data collection and management is beneficial. This exact sentiment was also expressed by a member of a farming team in their exit interview (see Section 6.2.10 on ‘Time’):

> I think when growers get to a scale where they have units of management that are just beyond where the brain can remember, that is where systems start to help. Systems should bring that information back to you in ways that become contextually valuable, and that the onus is on us as a solution to make it easier to use, easier to track.

6.2.5 Digital Literacy

The issues around digital literacy that transpired from the interviews can be summed up by one statement from a Commercial Provider: ‘understanding what software is, how it works and how it can benefit you, that piece of knowledge and learning is our biggest barrier’. Or, as another provider put it in relation to PA, ‘What does variability mean? How does it affect profit and the next bit is understanding how to use the software tools to build the knowledge about a particular individual farming system?’. Thus, digital literacy requires a much broader definition than computer literacy; it is an overall understanding of the potential of digital that can be taught. The providers considered that education on the potential of digital was required: ‘the return on investment is there, it’s just about convincing, that’s the wrong word, it’s about educating people on what their return on investment [can be].

These statements identified three parts to digital literacy: the fundamentals of digital, the technical application and the psychological aspects of delivering on perceived value. Consequently, a large part of suppliers’ efforts around digital literacy needed to initiate changes in thinking and attitude to stimulate adoption. However, there statements did not always suggest that providers took responsibility to enable this mindset change:

> Unless people actually delve in and start to adopt some of these systems we are never going to progress. It's a mindset change.
>
> That is another barrier, the fact that growers have to get used to the idea of software as on ongoing cost, not a one off.
>
> If you can create that learning environment where people are willing to share information and gather ideas from each other, start to become their own thought leaders, that is going to drive that mindset change that we are looking for.
>
> I find the difference between those that get into this and those that don't, the difference is an enquiring mind.

A major challenge for DA adoption, is to change the perception that it is the same as PA. Even one interviewee stated, 'I struggle to find the delineation between digitising farm records and precision ag'. Many reported that the farming industry is still struggles with the change to PA: 'I think the number one is the lack of understanding of what precision agriculture is, how, if I am going to do this, do I get started'. If PA is already considered too hard, then aligning DA with PA could be detrimental and needs to be considered seriously when trying to promote DA adoption: 'If you talk about digital, they think of precision ag, they don't think of the wider scope, marketing and all those other services that come together'.

Achieving mindset change requires education to help users understand what digital offers and why change is viable, and learning the language. In this instance, education relates to building knowledge, ability and confidence to lead to adoption. Suppliers recognised there was a general lack of education in the how and why to use digital tools. They gave few examples of how they were working to improve this: 'We do spend time educating people about what sort of things to look for in data, how data works and those sort of things'. Statements mainly acknowledged this lack of education or enthusiasm to change:

> Lots have got the ability and they don't do it, and you talk to them about it they say they would like to do it but when push comes to shove, they just let it go and that's the end of it.
>
> They are quite good on their phones and mobile devices but just when it comes to the office, they don't want to know about it, they have got no patience, and something goes wrong and they go that's it, I've done that. I actually think it's not so much digital, its more that they don't see it's their job.
>
> 95% of farmers probably don't know what a shape [file] is, so I think there is a language that we use that's probably not yet common.

Unlike for education, support relates to building knowledge to enable ongoing and greater use of technology. All suppliers reported multiple ways in which they delivered support. As one interviewee stated, 'you are paying money to use to use this product, you damn well should be getting as much out of it as possible, we should help you do that'. Support ranged from face-to-face, on-ground training, to providing answers to frequently asked questions (FAQs) and to instructional videos. Developing communities of practice and working with the whole data community were also considered important methods of ongoing support. The difference in methods to reflect different abilities and learning styles was also mentioned:

> For an inbound query, someone can either call, chat to us directly through the product or they can shoot us an email. The other [way] is facilitating self-help support—some people just want to solve their own problem—understanding what the key concerns are, making sure we have accessible help articles, that are up to date and answering the most important FAQs.

> You have to understand learning styles and that's about one-to-one interfacing but it's not a very scalable way of dealing with the market. The next best thing is having videos, YouTubes.

In between education and support sits the user experience of the technology.

To stimulate uptake and ongoing use requires an excellent user experience, which includes systems being easy to use and providing clear utility: 'I think a lot of companies under value the user experience with the data. It is not only the information you deliver; it is how you deliver it' and 'We have got to make this operationally functional and efficient, or farmers just won't do it'. The responses from suppliers of all product types often conveyed some frustration regarding the ease of use or unnecessary over complication of DA. However, at the same time, some providers seemed to shift the blame to others: 'Digital literacy, that's a problem, it's the fault of the companies that are making this stuff, to make it easy is what we try to do. You don't need any digital literacy; you just need a web browser'.

6.2.6 Influencers and Influences

'Once the grower understands a clearly articulated value proposition, he will go after it', but as was evident from providers' statements in other sections, it was not seen as that simple. The people in an adopter's networks are known to significantly influence adoption of new technology (Rogers, 2003). In this section the influencers and the factors that influence adoption or non-adoption of digital technology and approaches are addressed. With regard to influencers, three key themes emerged: trusted advisers, age and the role of women. In terms of influences, clear, credible communication and social proof were key themes. However, the theme of ease of use, which has already been broached in other sections, again came to the fore.

Two key trusted adviser roles were identified for a family farming business: those of the accountant and agronomist. While the accountant was found to encourage, facilitate and support the transition to online accounting software such as Xero, the agronomist could be a positive or a negative influence on digital adoption. Many of the statements in this section specifically refer to the adoption of PA and the role of the agronomist:

> There are a lot more agronomists getting involved now, which is a great thing; without them being fully engaged the whole process is pretty fragile.
>
> Having engagement, real engagement of the agronomist is really important.
>
> We recognise that for farmers, the leading influencer is an agronomist.
>
> He [the agronomist] doesn't have to be the one pushing buttons, using the software to the nth degree. But he needs to understand that process and be supportive and engaged with it.
>
> All these companies coming in from overseas try and cut out the agronomist because they want to get direct to the grower and sell them products. They completely ignore the agronomist and forcibly remove them from the process. They are absolutely kidding themselves.
>
> Getting basic tools in agronomists' hands is absolutely the first thing we have got to do.

Situations where agronomists were considered negative in terms of the adoption of DA related to the issues of knowledge, interest, time and the fact that the technology could result in long-term recommendations being changed. All of these issues are reflected in the following comments.

> Agronomists saw this as nothing to do with me, you guys come and do whatever you like.

> The agronomists are saying, I don't know anything about it. Then they come to us as a business and say my farmers keep asking me about this stuff, I don't know what I'm doing.
>
> Because their agronomist comes out and says let's do what we did last year because we know that works.
>
> In the past they [agronomists] have all been threatened by this but, in the last two years they have gone, 'look there is something in this, how do I get into this and how do I do it as easily and cheaply as possible?'.

The following statement relates to fear of changing agronomist and losing data. Loss of data was commonly discussed in relation to changes in software or platforms, rather than personnel, illustrating both need to be considered by providers when demonstrating value proposition: 'I sometimes do wonder if people are scared to change to a more progressive agronomist because they think they will lose all their data that they have collected over the last 10, 15, 20 years'.

Several interviewees mentioned that uptake was more likely by younger people. The influence of age appeared to be irrespective of role, with younger advisers, farmers and office managers reported to be faster and keener adopters. Considerable emphasis was placed on everything changing with the new generation, but these users would still need to see value in the use of a digital proposition:

> Probably in the last 5 years, the things have changed, it's a new generation.
>
> That generation are digital natives, they have grown up with a computer, done everything on it.
>
> The guys they had around the table were their young agros, the guys who are tuned into it [DA].
>
> Younger farmers are very interested in tech, generally speaking.

> The age group there was predominantly in the 30–35 age group, they are sort of a different generation, they are more internet savvy.
>
> Now we can talk to the younger farmer who has moved back, who may have a young family, who knows we need this to be farming in the 21st century and so they then become our advocates to go and talk to the cheque book holder.

The majority of the quotes reported from the providers indicate that farming was considered a very male-dominated business and that the term ‘farmer’ was not gender neutral: ‘I was thinking about the farmer himself and what stage of life he is at, and whether precision ag or digital agriculture is even important’. However, the role of women in farming businesses is becoming more visible, especially as technology increases because they are often found to be more digitally literate than their male counter parts in farming businesses (Hay & Pearce, 2014). As can be seen from the following quotes, this could have a positive or negative impact when it comes to adoption, because of the need for information to be accessible to all members of the farming team:

> My opinion is that the *SHE* is much more value and detail orientated. *HE* might be the figurative head of the organisation, *SHE* is the CFO [chief financial officer] and the COO [chief operating officer], *SHE* is not just the finances, but she is also increasingly about the data and those pieces of the puzzle.
>
> One challenge they [women at a digital ag workshop] identified is what they see as barriers, is the fact that there are others in the business that have to be brought into that [new software], so the mother-in-law, the husband, the father-in-law, who don’t have an understanding of the value proposition, they have a certain fear about this digital environment, they cannot easily find stuff when they come into the office.

Irrespective of age, ‘One thing we have found is that you cannot unlearn things’. Thus, a good user experience was seen as essential from the first interaction with the technology. For many, that first interaction would be online: ‘You have to be really careful about the condescending language, even on their websites it comes through’. Social media was seen as an important platform for sharing knowledge and experience, good or bad: ‘They are all on Twitter, they follow people, they are very active. So, as one interviewee stated, ‘It’s about messaging, it’s about articulation of value and it’s about user experience’. As another stated, this could be difficult, ‘because it all just seems too complex’.

All software products discussed during the commercial interviews were offered with a free trial period to help demonstrate value and enable user experience. While actual interaction was seen as valuable, proof of value from a trusted source was also highly influential: ‘One of the most powerful sources is that sort of peer results, social proof is an incredibly powerful force’. The credibility of the supplier as well as the product was seen as important, especially where backup was required:

> I feel like I have been very fortunate to have fallen in the space that a) I come from a family farming background and, b) I spent 20 years being an agronomist, so I can stand with a farmer and say this technology is going to help you grow.

Where systems were mandated and required for compliance, uptake of digital solutions had been accelerated. Tax accounting was one example, but two examples relating to selling produce were also shared. As these mandated systems started to interface with production, the uptake of digital outside the business administration functions was likely to accelerate, a projection supported by these comments:

By 2020 they [CBH Group, bulk grain handlers] are not going to have paper-based delivery forms. So, farmers are being pushed into this direction through these various parts of the chain.

We have customers able to join quality assurance schemes because of AgriWebb, that they weren't on before, it was to allow them to meet those [data] requirements.

6.2.7 Digital Technology Ecosystem

Participants acknowledged that users often expressed the wish for a single piece of software to do everything: 'Many growers say they want one thing that does it all. In reality, there will never be one thing that does it all'. Providers understood this desire because 'growers battle with having, four, five, six different bits of software that they use for different things and they hate it, they absolutely hate it'. However, they indicated a degree of exasperation at this proposal as it was considered counterintuitive because of the cost burden for a single company and because innovation would be inhibited:

No one can build everything in one box. We have to give that idea up. No one can come to market with everything prebuilt, perfectly ready to go.

Everyone wants one product to do it all, but that's irrational because if one product did it all you would either have to pay them $100 K a year or it would be a bad product.

Interoperability was seen as a key part of the solution: 'That's the power of interoperability. Because what you find is no one person has to carry the whole load'. Indeed, interoperability has been used at a superficial level to develop dashboards to display, and access to multiple platforms is progressing. These are solutions that provide a single access point to multiple data sources but do not necessarily integrate the data; more usually a dashboard is purely a method to visualise multiple data streams, but not to manipulate and integrate the streams for further analysis. The development of dashboards for displaying multiple data sources was becoming popular at the time of the interviews in late 2018. These integrated systems also enabled users to 'pick and mix' the solutions they wanted:

> We're creating what you call a digital dashboard that is configurable so that people in that situation can basically have a task list and for those task lists across the day look at all of the information that is important to make a decision on that day.

A portal—a web-based platform—was another solution providers were using to deliver the digital technology ecosystem. The value of these interoperable solutions is exhibited in one statement: 'a platform should have that interoperability, it should exchange, it should have a one plus one equals three outcome'. One aspect of interoperability related to data capture and avoiding repeating the entry of the same data:

> What technology should really do is ultimately bring disparate sources of information together for multiple purposes for multiple parties that have an interest in a subset of that information.
>
> Then we have to make sure that we are not collecting it again, and again and again and again, in different formats to run different tools.

Achieving interoperable solutions required collaboration between companies. This was achieved through the use of common data models, sharing of APIs and using open source software:

> Collaborative visibility is what we offer, which is uniquely an advantage over what was available in the past.

A collaborative solution is required, that is built on the technology of iPad, iPhone, website, cloud based and underpinned by a standardised data structures that enables users to utilise information.

We have the formats of most machinery embedded in our application layer. We can ingest that data in its array of proprietary forms and turn that data into a common dataset whether it came from a red, green or yellow machine.

We have developed a free smartphone app which is drawing in various sources of information through APIs and making that available to the producers.

We diverted out about four years ago, making a decision to move to an open source type interaction and dealing; we developed an interface with nine different labs across Australia.

The value of collaboration to suppliers of digital products and their end users was gaining momentum but was not without its challenges. These challenges occurred at a technical level but also at a market level because of the diversity of agricultural environments and enterprises:

So, collect it the right way in the first instance, then be open to interoperability with partners, so if someone can build a better tool than we can, that data can be made available to them in a format that is simple to engage with.

In Section 6.25 on digital literacy, the requirement for adoption of digital technology illustrated the need for users to have a mindset change. While this was an important first step, so was the availability and intersection of people with the skills to implement and service on farm digital systems. Together these people formed the data community:

When you think about the idea of a data community around a farm business, it flags up all those people that sit within the business and contribute to or benefit from data and those that sit outside the business that are interested.

> I think the industry has sort of software focussed people and farm advisory focussed people and then there are farm mechanics but rarely are they the same person.
>
> There is one smart for equipment and equipment efficiency and a second pipeline for agronomic knowledge or agronomic detail. And what you see is that today those two lines are beginning to merge.
>
> We are in a really good position because we have a great network of people who are working on farm daily and we also have the ability to support these agtech businesses that are bringing the technologies to the table.

The digital technology ecosystem was enabling farmers, their trusted advisers and technical support services to access data and machine settings. However, the diverse range of systems created investment and learning challenges for agronomists and others supporting businesses using different software, as one agronomy business stated, 'It is quite expensive when you start adding up all the different systems that are out there'. Comments from some service providers suggested they would let users take the lead on product choice:

> I don't believe we will ever be able to work with all the products out there but what we will be able to do is work with the ones that get the greatest adoption; so let the farmer choose what's the most practical and suitable system for them and make sure we can support them with that. It's a bit of a gamble.
>
> The bit we haven't worked out though is the financial side of how that works, because if you think about it from an agtech supplier point of view, how can they justify their expenses in developing and maintaining and running the programs. We would have to have a subscription across all of them and if I paid a full subscription for our agros [agronomists] across all of them I would

> be spending 20K [$20,000] to 30K [$30,000] per year per agronomist and that's just not sustainable.

This statement from one provider summarises the issues around the digital technology ecosystem and data community: 'It's a very complex environment across a very diverse range of production methods and products. It is just hard.'

6.2.8 Connectivity

Providers concurred that lack of connectivity was a limitation, but it was considered a diminishing barrier. Indeed, connectivity had the most statements coded to the subtheme 'success':

> I would like to say connectivity is a major barrier, because I go ranting around for ages saying we need to get connected and do believe in all the things people tell me about connectivity, and of course I experience it myself. But I am not seeing that as being a major barrier to people using our tools because they are getting better and better connectivity every day.
>
> Raw connectivity is terrible, thankfully our app works offline, most people seem to have some level of internet connection.
>
> There are still massive issues of connectivity, but the solutions are available. So, connectivity for example, we are in that execution phase now, we sort of know what the answer is.

Those solutions did have to reflect that DA may require different or additional connectivity solutions to those available to urban businesses: 'we are not all sitting in an office all day in an urban environment with high-speed internet'. Such solutions were considered to require private investment, because as one provider stated, 'What we know is that the government is not going to solve it, it's going to be private enterprise that solves connectivity'.

Connectivity required reliability and sufficient speed to provide the desired value: ‘Sometimes we can connect, but it’s not quickly and the speeds are not quick enough to actually utilise’. The rollout of the NBN had provided improvements in availability of connectivity at the homestead, but mobile and other solutions were required for connectivity across the landscape. Overall, comments about connectivity were positive:

> Satellite broadband has not been brilliant and there are still some limitations but its available. It’s clearly available enough for us to have this video conference call, which is amazing and that’s phenomenal.
>
> I can only think of one example where connectivity was so bad that someone had to drop the product.
>
> Once they realise the value proposition, certain people will go and create their own Wi-Fi infrastructure in order to get there.

Differences in opinion were expressed over the importance of connectivity to cloud servers in relation to promoting and supporting digital adoption. The first statement illustrates low value for the cloud improving data flows; the other three statements indicate how the cloud was regarded as integral to the evolution of DA:

1. The API is no different to what we do with a thumb drive, a USB stick, it just brings that data in via the cloud.
2. Somehow that whole operator error needs to be ironed out of the system, which we are moving towards with cloud based and stuff like that.
3. The ability to take that information and exchange it into other [sic platforms], this is the fundamental value of cloud solutions.
4. Initially it was the iPad to be able to record and upload it, but the cloud is definitely the integrating device.

The cloud was opening up opportunities for data sharing, real-time remote access of data and the ability for advisers to save time. One national supplier of on-farm services in Australia saw the cloud as so valuable they changed software to enable connectivity: ‘For over 9 years we were using the Back Paddock system and then we needed to go to the cloud and we went to Agworld’. The value of the cloud was fundamentally in data sharing, by offering, ‘the ability to take that information and exchange it into other [software], is the fundamental value of cloud’. However, several saw it as a solution that would help drive adoption: ‘The cloud allows these disparate or different data layers to flow to a common solution, for visualisation. Because remember it is the democratisation of the visualisation that really allows this to occur. That is what triggers adoption’.

The need for telecommunications connectivity varied between uses and products. Many had produced solutions to overcome the need for constant connectivity; primarily the use of native apps that could be used offline with data uploaded when in a location with connectivity. This did come at an additional cost to the developers, so some had opted for web-based solutions:

> While it [connectivity] is a massive issue in rural Australia it is not the be all and end all of stopping people doing precision ag.
>
> For the main job, which is recording stuff when out in the paddock, it [connectivity] does not matter largely if you have got that offline component of the software that you use.
>
> Yes, we have connectivity problems in many areas, so build native apps that work offline, but they still need to be able to sync to the cloud when you have connectivity.

> We have worked really hard to get our tools to work effectively on low internet connectivity, but they don't work offline; it would cost a lot of money to do that.
>
> PCT AgCloud operates entirely on the web and the advantage of that is through APIs—I call them pipes—we have and the ability to talk to other companies.

The development of local, rather than global connectivity solutions using Wi-Fi radio networks and narrowband connectivity options was also discussed. Many IoT devices did not require constant connectivity and the gateway provided an interim storage option. However, providers reported the cost of establishing such networks was dependent on the types of use and number of devices. They were not without challenges because of the need for line of site for terrestrial solutions:

> We see the internet of things as opportunity; farmers can see the value in putting in weather stations, sensors, soil moisture sensors, probes and connecting into LoRaWAN networks.
>
> Our system is designed that the gateway can hold weeks of data until it connects to 4G.
>
> If your farming businesses are looking at two or three or four sites, it is probably still worthwhile, with cellular networks. But if you start looking at 10 monitoring sites across a farm, then the radio network is where it is going to be at.
>
> If you have 3G, 4G on each node it's going to drop out and you are going to lose data and you don't have accurate data to give back to the growers.
>
> We are going through some pain at the minute with [telecommunications] connectivity versus Wi-Fi and distance, and having Wi-Fi around the farm,

where is the best spot to have it and how far will it penetrate and all that sort of stuff.

PA *per se* did not require connectivity to the telecommunications network. However, the addition of connectivity via telematics and the cloud enabled remote diagnostics, file setup and data sharing. It enabled data, machines and people to be connected. Possibly the bigger issue with PA and machine connectivity was compatibility of systems:

> The thing that is really driving this technology from the agronomic side is telematics.
>
> Being able to get the telematics data and to confirm what has been done where and confirm that things are on site.
>
> It's not just the telematics, but the telematics with visualisation, with the democratisation on things like smartphones, on things like tablets.
>
> The major machinery players have got their act together and provide enough of a suite of each one [sic rate controllers, yield monitor]; they haven't overcome it but they haven't made it a lot worse.

The tablet and smartphone ushered in a new era of opportunity for displaying and accessing data, which had been augmented by broad and narrowband networks and the cloud. However, these final comments on connectivity illustrate that reliable connectivity was only one piece of the digital technology puzzle:

> There has been a need for them to access their data on multiple devices wherever they are. So having it on the web allows them to access their data that way.
>
> I think having it all in one spot is one thing, the next is getting it to seamlessly work together so two sets of information that come from two different sources

can actually work together to generate another outcome that they wouldn't have been able to do on their own.

6.2.9 Trust and Legal

When asked to rank the barriers to adoption, 11 of the 14 providers ranked trust and legal issues fifth of sixth (Figure 6.1). On the aggregated top three scores, this barrier was ranked the lowest (Figure 6.2): 'A lot gets talked about trust and legal, but I don't see that as hot, it's a bit of a non-event; it probably shouldn't be'. Another stated, 'the idea that their farm data is going to compromise them in one way or the other, is a real issue in farmers' minds, but I think it's a furphy'. However, in text analysis, 70 statements were related to trust and legal issues, ranking it the sixth-highest theme among the 10 identified: 'I think the trust one we are overcoming that, slowly but surely, even though it is a major issue'. Indeed, one provider stated, 'people make assumptions, and ironically, they assume the worst can happen not the best'.

The providers' statements, rather than ranking, were more closely aligned with the P2D finding that 56% of producers had low trust in providers maintaining data privacy (Zhang et al., 2017). In this analysis, issues of trust embraced data privacy as well as trust in the continuation of a product or service for that product and trust in the reliability of products. There was minimal discussion regarding trusting the data beyond the need to ground truth data to a specific location or situation. The lower score for trust and legal issues when ranking the barriers was reflected by the attitudes of suppliers regarding issues of data privacy:

> If they don't know where their data is stored, and how their data is going to be used and they choose not to find out and not to engage because of concerns, then that becomes a barrier through apathy, not through the fact that there is any risk.

However, some providers still saw this as a barrier to adoption: ‘I think because of data privacy issues and fear around those things, I think people shy away from digital products’. An interesting point related to the difference in expectations and laws around privacy across the globe, which had to be considered for those working in an international market: ‘America and Germany have very, very different privacy laws they have very different perspectives in relation to data privacy’.

Data ownership was often regarded as a greater stumbling block to adoption than were concerns over data privacy: ‘there are arguments about who owns the data, that’s a big one’. Ownership and privacy were both covered by the terms and conditions of data licences and several suppliers considered that the option to opt out provided users with sufficient protection. Others suggested that this issue left many questions still to be answered:

> Data ownership is a massive one, I know that. And something we have not fully explained to our clients, but we have not had any kickbacks or major questions to use in relation to that either.
>
> There are still a whole heap of issues that need to be resolved publicly about ownership and stuff like that but I think we have a lot more to gain than we have to lose, to be honest.
>
> That sense of privacy and who has access to the data has become more principled. Now it’s all explained in our terms and conditions. So, we have a data privacy policy and we have a reuse policy.
>
> Growers need to understand that any digital system they use, they can opt out, they need to accept ownership of their responsibilities for the use of that system.
>
> They can choose to exclude us from viewing their data.

Several suppliers expressed concern over the difficulty of developing clients trust to share data with corporations; a problem that was minimal if data was to be shared with a trusted adviser. This need to build trust again, the issue of changing mindset was raised, this time in relation to the difference between control of data as hardcopy and digital sharable data: 'if you are writing it down in a book, it's very much in your control'. The ability to share data was considered of high importance: 'data is currency'. However, the only concrete solutions to building trust were articulated in relation to having separate systems, building 'rigorous sharing protocols' and education:

> You don't have native trust that collecting and sharing data will not end up hurting you or causing you to have an opportunity cost. We can solve trust if we build rigorous industry data systems.
>
> But the way you can sell value proposition is to take away stress in their life so if you have a separate yield monitor in the harvester then you know that data is being collected, its safe, its secure, it's there and you own it.

Providers considered data sharing with trusted advisers was not a problem, even if via a proprietary product. Similarly, sharing data in situations where all parties gained value or reduced risk broke down caution:

> If a grower is working with a trusted adviser that's not a problem, but if it's being provided by someone else they're not sure of that [*lack of* trust] probably floats right to the top.
>
> I don't think we have a lot of trouble getting collaboration with farmers to share their data, providing you can actually give value back.
>
> Everyone involved in that situation [neighbouring famers and spray contractors] had the same data and knew what was going on and potentially saved a legal situation of being sued for spraying.

> I seek permission from all the private site owners to use their fire danger index information in an aggregated form for the CFS [Country Fire Service] or council.

The loss of data because of ownership issues between advisers and clients or, more commonly, suppliers moving out of the market, were concerns providers had experienced. One provider recognised the risk of entering a new market both for the seller and the user and another illustrated how farmers liked to see a proven product before they invested:

> If the farmer's happy to share that data, we should be able to bring that into other systems instead of trying to reinvent the wheel. You can lose 10 years' worth of management data, otherwise.

> The risks are incredibly high, if a grower is relying on your product and it doesn't deliver, that is a big risk for a grower because they can lose an entire crop.

> We need to stop this idea that all we need is a start-up and we will have it solved. It's a long-term play, we need long-term vision, we need long-term capital.

> When you go out with something that is really minimal you can hurt your reputation, and in this particular industry there have been so many fly by night companies.

> It is very rational for them to say, 'you know what, let's see if you guys are around in a year, let's see what happens, let's see if people actually get results out of this'.

6.2.10 Time

One statement typifies the comments commercial companies regularly received from potential users regarding starting or progressing their use of digital: 'I know I need to start being digital, I know this is important to my business, but I just don't have time right now'. They recognised that farmers and agronomists were 'super busy', and that changing from a trusted to an unknown practice was 'the last thing on their list'. Indeed, one service provider reported, 'I think one of the biggest barriers for our business for adoption is time'. Making change took time to implement, and time to research: 'There are a lot of "sharks chomping", saying "we have this data model and sensors, and we can solve the world's problems"':

> They get so busy and flat out; even the potential that this will save them time in the long run, that the short-term pain of having to learn something new and having to sacrifice time now is almost too great
>
> What we have found is that the average person who gets to the point of converting, they're not spending 90 days incessantly working on it, they usually know within a couple of hours of usage.

These examples illustrate that the theme of time involved more than lack of time, it was also about the need to change the perception from digital taking time to saving them time. Software, hardware, connectivity and data, and combinations of these elements, had all begun to show time savings, but as one provider of software stated:

> one thing we would love to try and do is a better job of expressing that digital tools save you time … It might be as simple as a tank level sensor; it just makes it easier to understand or to have that information on your phone rather than drive two hours to check something.

Examples of time saving from using digital were provided by several participants:

> It was amazing, the audit [using AgriWebb] took one tenth as long.
>
> He saved 3 hours in one paddock alone checking his lentil desiccation recommendation [using Normalised Difference Vegetation Index (NDVI) imagery].
>
> Using Agworld, an agronomist can save two hours per day in terms of day entry. He can do them offline, in real time with the customer and not have to go back to the office to enter up recommendations or observations.

Yet, there is *no gain without pain*, and one of the pain points of digital was that often there needed to be a commitment to setting up and using the system. This demand for time to be spent before value was delivered was seen as an adoption barrier:

> The benefits only come from people adopting—that means that there needs to be investment in time and commitment to process to actually realise the benefit.
>
> If it’s hard to do and takes them more than 10 minutes, then most growers are going to go ‘well bugger that’.
>
> Autosteer have had 80% adoption rates because you implement it and get a benefit straight up; the machine drives itself. A lot of technologies you turn them on and then you have to create information within them before you start to get a benefit.

To understand users’ needs and situations required developers to take time. Several providers reported the importance of spending time on farm to learn, and to build trust and confidence in their products. Developers who had been in the agricultural industry for many years compared their ability to deliver to farmers with that of newcomers:

> I see the new kids on the block who have been in the industry for 12 to 18 months, even 2 years, with no practical concept of how the data is being used. I spent an enormous amount of time to going back out there to meet with people as much as I could.
>
> I am the only one stupid enough to drive all around the countryside and install sites and keep servicing sites.
>
> It's more about people looking for those specialist services and we now believe the time is right for that.

Several providers referred to the transformation from manual to digital to digitised as a journey: 'growers need to understand they come to a technology, and they go on a journey with technology, it's not "I use it now and that's what it will always be", because it's evolving all the time'. The digital journey had only just begun: 'we are still at the beginning of the real adoption curve, we're immature'. This journey was occurring in the product development field as well as the on-farm use of digital, and for many that journey was only just starting:

> Over the last 5 years or so the world has changed and machinery platforms are more interoperable. They were very bespoke and now they recognise they have got to be part of a broader story.
>
> As we build our CRM [customer relationship management] tool it will build efficiencies in the way we work.
>
> The agronomic side really only started to embrace this in the last 3 to 5 years; they are just starting that learning curve, they are just starting to cross the chasm for variable rate technology or the embracement of digital agriculture.

Another dimension of time related to solutions being presented at the 'right time'; 'some of the technology is ahead of the need at the moment'. The idiom says that timing is everything and that held true for digital. Timeliness was not just being the right time for the overall market maturity but also in relation to seasonal demands on time and turnover of data. Being timely could be difficult in such a fast-moving market:

> At some point, there is a tipping point where businesses realise that if I don't have [accounting software] a MYOB, or a Xero or a QuickBooks, I am behind, I am doing myself a disservice. That point will come in agriculture.
>
> In a crowded market, first to market is, you know, really important.
>
> You almost need to time when you launch or release; it's a time thing, so to learn something new takes time.

However, this omen from one service provider casts a shadow over the speed with which adoption barriers might be overcome. They foresaw that, 'It is just going to get more, and more complicated and more computers.'

6.2.11 Data Analysis and Decision Support Tools

Data analysis is the missing link if data are to be used to improve decisions, actions and outcomes. A range of subthemes emerged ranging from use of data and DSTs, to digitally integrating the data stack. Service providers considered, 'There is plenty of data analysis and decision support tools' and had even given access to these calculators through a cloud-based subscription. Of the six original themes, data analysis and DSTs had the least number of statements coded to the theme (Figure 6.4). The low consideration for digital data analysis undermined the value of data and its perceived usefulness but as one provider stated, 'if their knowledge is just stuck in their head then no one can help'. Where data were recorded, spreadsheets were viewed as the first step towards digitalised data:

> They have their spreadsheets that they trust, but it is mainly with a spreadsheet because there are a lack of options.
>
> You know the data analysis capabilities of paper and pencil are pretty low, so we are improving on that I think we could do a whole lot more.
>
> If someone can get their value out of pen and paper, they should use pen and paper. But you might need a digital system to extract the value that's important or valuable to them.

Some saw the lack of use of analysis as part of the problem (e.g., 'the trouble getting them over the hurdle of the actual analysis') while others considered that to stimulate the transition from manual to digital recording systems, developers had to keep the systems simple: 'Keeping it simple and focussing on issues that the farmer can directly relate to is really important'. Ultimately, suppliers envisioned the use of artificial intelligence but the first step was to have the data they needed in an accessible format so that it was used, because the view was that, 'at least 80% of the people I talk to do value the data', but that did not mean they used it to its full extent.

Statements relating to data integration were reported under the value proposition, data availability and ecosystem themes. However, they are also relevant in this theme when specifically related to data analysis and the use of the data stack to improve management outcomes. One provider involved in delivering services reported he regularly used seven data streams and software to support on-farm decisions, and that excluded any tools for benchmarking or financial analysis:

> At the moment we use Agworld for recommendations and planning with our clients; we use several forms of NDVI images; we use EM38 surveys; so we do our own surveys there and then we're using either Farmworks, the Trimble

> system for analysing ag data and some of the guys are using QGIS [an open source Geographic Information System] and some are using say MyJohnDeere-type thing. As you can see there, there are so many tools that we need, software, in order to get to the end point.

However, in many instances, existing systems for integration were seen as limited or difficult to achieve. It was considered that improved systems of data integration rather than more analytical tools were required, if digital data use and digitised processes were to be adopted; but none said it would be easy:

> You begin to assemble these solutions and then the challenge is how to bring together all these different data layers, because it is hard.
>
> We have to use a lot of different tools to get to the end point and it’s a bit messy.
>
> Well there’s a … load of decision support tools out there that aren’t getting used, it’s not that there is a lack of them, there just not in the right format, there not integrated.

6.2.12 Individuality

Initially, individuality was coded in relation to statements about the individuality of the farming business; for example, ‘the thing about farming is that everyone operation is so different, so bespoke and everyone’s management techniques are so different’. Through the second round of coding, themes of individuality or diversity of seasons, enterprises and business structures arose: ‘Every farm within reason operates a little bit differently, so you need to be able to appreciate and understand’. Others stated:

> Every business is a little bit different; a grain farm will be different from a potato farm and a tomato farm is different from a carrot farm but my first question is what are the KPIs [key performance indicators] for your farm. There are not many growers that I see that are driven by profitability. They are driven by so many other things, just as humans we are all driven by different things.

In terms of PA, one supplier stated that ‘Australia and New Zealand is a very unique microcosm that is 5 plus years ahead of the world’. However, this could create a limitation to innovation development because, ‘as a company you want to single global product that fits all geographies’, let alone all farming businesses within that geographic region.

Providers reported that individuality was confronting because:

> The challenge is everybody has different things that they want.

> There is not one size fits all, there needs to be consideration of the human side.

> Everyone has an opinion and it’s always different on what data they want to see and how they want to see it displayed.

The only solution to dealing with this individuality was to embrace the differences. Ideas for how this should be done were not forthcoming. The acknowledgment by the providers of the challenges of individuality reinforced the potential for improved dialogue between all players in the DA ecosystem.

6.3 Digital Agricultural Adoption Ecosystem

Section 6.2.7 reported the emergence of the desire for a digital technology ecosystem, relating to issues of equipment interoperability and equipment compatibility. Yet the thematic analysis clearly indicates that barriers to adoption are greater than technological limitations. Indeed, the analysis closely aligns to adoption theory which indicates the combine impact of the technological and sociological factors on technology adoption (Rogers, 2003). The presentation of the six barriers to adoption in the P2D Summary Report (Leonard et al., 2017) implies that improvements in legislation, education as well as the technologies will drive adoption. Yet little regard is given to the deeper sociological issues of human perception, and individuals' specific situations. Based on the 10 themes described in sections 6.2.3 to 6.2.12 a new approach to considering these influencing factors is proposed. These 10 themes were divided into technology and data issues—data availability; connectivity; and data analysis (DST)—and people issues—value proposition; digital literacy; trust and legal; influencers; influences; and individuality. Each theme is associated with the subthemes that emerged from the analysis. Presented as interconnected rather than siloed factors, these themes become the structure of the digital agricultural adoption ecosystem (Figure 6.5).

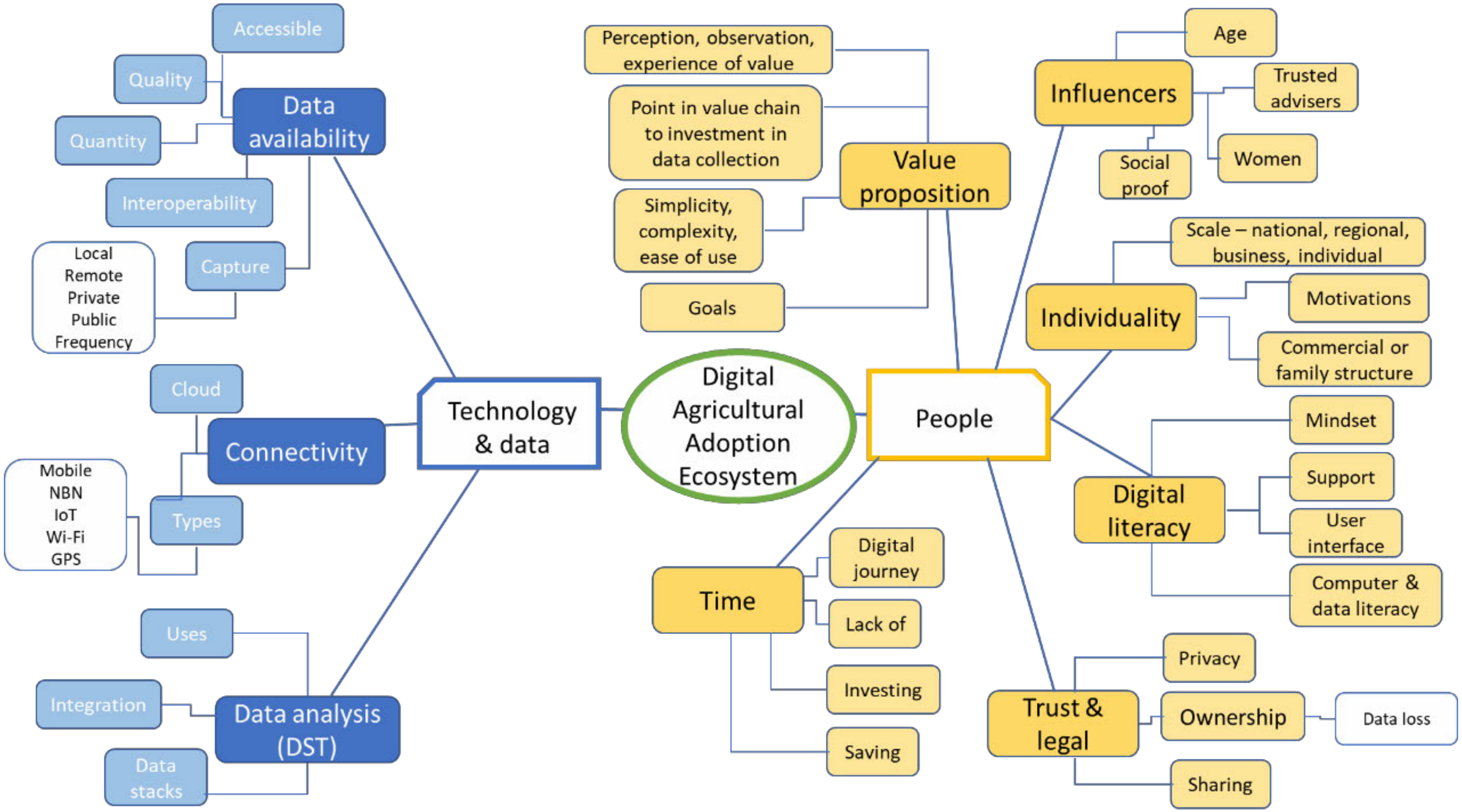


Figure 6.5

The Digital Agricultural Adoption Ecosystem Created from Thematic Coding of the Commercial Interviews

6.4 Summary Chapter 6

The commercial interviews provided insight into perspectives on adoption from providers of digital hardware, software and services to cropping and livestock producers. The six barriers from the P2D summary report provided the focus for the interviews. Analysis of the transcripts identified that these barriers are highly interconnected; not siloed as initially presented in the P2D Summary Report (Leonard et al., 2017).

The original six barriers were considered to still exist, with only connectivity reported to be achieving some success in being overcome as an adoption barrier. In addition to the six themes of value proposition; data availability; digital literacy; connectivity; data analysis and DST; and trust and legal issues, four additional themes emerged: the digital ecosystem, influencer, time and individuality, plus multiple subthemes.

The issue of value proposition dominated the discussions and received the highest ranking of the six original barriers to adoption. This has been allocated to the people part of the ecosystem because the statements reflect that it was the human perception of value provided by the digital technology or service that determined adoption, not its financial cost. While the P2D project presented the barriers as six separate elements, this predominant lack of digital value proposition can be viewed to be influenced by limitations in the other five barrier areas. That is, the barrier of lack of value proposition is not mutually exclusive in relation to the other five barriers, but is interdependent.

Providers were able to articulate the barriers and how these were experienced by their businesses, but offered few solutions. Most solutions related to providing good user experience, free trials and support. The importance of providing simple, easy-to-use systems that meet a need were all elements required to overcome many of the barriers, providing the solution was at an appropriate price point. They recognised a demand for an all-encompassing system but acknowledged this was neither feasible nor viable. The conflict between meeting individual needs and gaining a sufficient market share to support product development continued to challenge the providers of digital technologies to family farming business.

Some frustration was expressed by the providers regarding farmers' apathy about adopting digital technology. They also noted that many of the existing digital offerings were just too difficult to implement for the potential return. Conversely, enthusiasm was expressed over the potential of digital to provide on-farm and along-value-chain solutions, and in the fact that technologies and connectivity continued to improve.

The demand by users for one system, but the specific needs of individual sectors, business structures and even people means one size cannot fit all. This is a conflict that the suppliers of digital technologies recognise but they continue to grapple to find simple, user friendly and useful ways in which to overcome these barriers. The analysis of this embedded research study identified that the definition of the barriers identified by the P2D research needs to be considered as an ecosystem, with themes aligned to one of two groups, technology and data influences and human influences as presented in the Digital Agricultural Adoption Ecosystem (Figure 6.5).

Chapter 7 reports on how video tutorials and open questions were used to gain an in-depth understanding of each team member's digital change priority from a process perspective and their perceptions regarding applying a change management approach.

Chapter 7: Results and Analysis—Video Tutorials

Via the video tutorials, all participants were asked for an example of an on-farm process they would like to be digitalised. These real-world examples provided a foundation against which other video tutorial questions were posed. This chapter presents the results gathered using the video tutorials. These data helped illustrate the complexity of on-farm digital processes, the language used and the need for data to be delivered in formats that can be integrated, analysed and controlled by the farming business. Responses to the video tutorials provided greater insight to support answering the first part of sub-question RQ2 *Why and how do farm businesses initiate the use of digital technologies for farm management?*

The six video tutorials produced as part of this research were designed both to inform the participants and as a data collection instrument. Initially, they were designed to engage with the project and test the appropriateness of the adoption framework. As the responses and feedback were gathered, it became increasingly obvious that the adoption framework could prove helpful; it was the evaluation of the current state that was crucial because of inconsistency of responses from within teams. Consequently, the information gathered by the videos was used to develop and support population of the evaluation tools. This chapter presents the participants' feedback on the use of videos and in response to the open questions posed.

From this point forward, data collection was from 17 participants only because of the departure of Team 3's Trusted Adviser from the research for personal reasons. All team members responded to all questions, with the exception of one at the end of Video 3, which was not answered by one Manager of Team 2 due to personal time constraints; and one in Video 4 that was not answered by the Operator because of an email account problem.

The open questions posed in the videos were answered via email or text message; the response method was the choice of the individual. Videos 1 and 6 provided updates on the project, with a question in Video 1 asking viewers to contact the researcher if further information was required. The question relating to Video 6 was included in the DKSA validation questions: ‘How well do you think your score and the definition reflect your digital knowhow?’. Thus only the data collected from Videos 2–5 are reported here.

The use of videos was received positively by all teams. Some wanted more information as the video had stimulated thought and discussion. Comments included:

> Team 1: ‘I cannot think of a better way. You could have come face to face but then you don’t reach many people. I probably rate as nearly as good as face to face. I don’t have the interaction back with the video. Emailing back, that was probably beneficial to the process as it did give me time to think about my answer and give a more correct answer’.
>
> Team 3: ‘I would say you get better engagement out of a short video, it has to be short’.
>
> Team 4: ‘Certainly, easier than reading. I prefer them [videos]—more authentic and real and conversational like you put together. So, they were fine’.

7.1 Video 2

Video 2 theme: ‘What is digital agriculture?’

Video 2 question: ‘Which process would you like to digitise first and why?’

The question came with the caveat that there was no capital, technical or skills limitations; this was their ideal change. Each team member provided an example of a process they wished to digitise. The objective of this question was to test the first element of the adoption framework.

Processes selected included production operations, business administration processes and changes that would primarily improve efficiency, occupational health and safety (OH&S) and peace of mind. These processes reported by team member in Table 7.1 to Table 7.5. The same process was never the priority for change by all team members. Team 5 (Table 7.5) proposed different processes but these all related to the common goal of improving water use efficiency. Consensus was not seen even between all internal members of a team (i.e. when the Trusted Adviser response was omitted), although there was often consensus between two members of a team. This disparity in choice of process to be digitised first provided an insight into the individuals' needs and digital knowledge in relation to their responsibilities.

7.1.1 Team 1

All members of Team 1 provided a process relating to livestock management, the enterprise from which over 75% of their income was derived (Table 7.1). Remote monitoring of different items was of interest to the Manager (real-time monitoring of individual sheep) and the Operator (water troughs and feeders). The manager specified this monitoring was required in real time, while no time frame was specified by the Operator; however real-time monitoring of water and feed is not generally required in broadacre livestock. The objectives for their choice of first process for digitisation were unrelated, being security and production efficiency for the Manager and efficiency for the Operator.

The Trusted Adviser—a family member who at the start of the trial worked off farm as a livestock adviser but was transitioning back to the family business at the time of the videos—proposed production management; specifically, sire–dam pairings to be driven by integrated production data to help the business focus on profitability. Complexity of the solutions and potential returns would increase from that proposed by the Operator, to the Manager and then to the Trusted Adviser.

Table 7.1

Summary of Responses by Team Member to 'Which Process Would You Like to Digitise First and Why?'—Team 1

Team 1 role	What	Why
M	Real-time, remote identification of individual sheep	Security and productivity management
O	Remote monitoring of troughs and feeders	Efficiency
A	Integration of individual animal data from key profit drivers—wool weight, micron and body weight	Selection of most profitable bloodlines

Note. M = Manager 1, O = Operator, A = Trusted Adviser.

7.1.2 Team 2

In Team 2, both Managers nominated to digitise a production management process that related to improving profitability, but within their enterprise of interest: cropping and livestock, respectively (Table 7.2). Both Managers suggested changes focussed on the digital collection and use of data, in terms of factors considered to drive profitability. The Operator suggested a more production-specific and task-oriented change relating to logistics and application of herbicides. The Operator's change was motivated by reducing costs, while the Managers were looking to improve profit. These aims may not be mutually exclusive but were not necessarily compatible. The Trusted Adviser (a soils specialist) sought a specific change in their area of expertise and service provision, which related to that of Manager 1. No member specified the frequency of data collection required for the process.

Table 7.2

Summary of Responses by Team Member to 'Which Process Would You Like to Digitise First and Why?'—Team 2

Team 2 role	What	Why
M	Data to understand returns at a paddock and then spatial level Full automation of the creation of input prescriptions at seeding and top dressing and integration with yield data	To calculate profit at a paddock and sub-paddock level and improve understanding of impact of management profitability. Improve efficiency and less errors
Ma	Lifetime individual sheep tracing and association of data relating to profit drivers – e.g., days not pregnant, wool and meat weights/yields. Automated establishment of productions groups and linked to virtual fencing	Identify most profitable animals and implement individual sheep management to improve efficiency of resource use and productivity
O	Digital weed control for accuracy and chemical inventory	Reduce chemical costs and know what chemicals are required
A	Detailed, digital soil and landscape maps	To provide the base layer for production management decisions

Note. M = Manager 1, Ma = Manager 2, O = Operator, A = Trusted Adviser.

7.1.3 Team 3

Each member of Team 3 proposed changes to production and operational processes (Table 7.3). Manager 1 and his wife, the Operator, both wanted to digitalise the spray application process for pesticides and liquid nutrients. For Manager 1, the objective was to minimise exposure to chemicals and for stock control. For the Operator, whose main function was administration, this change was to improve efficiency by achieving the data flow through to management and inventory records, and to improve work health and safety. They explained that the spraying process was targeted for digitisation because this equipment was used across the farm five to eight times in a growing season, whereas sowing equipment or harvest covered a paddock only once each season. In contrast, the objective of Manager 2, their son, related to production data flows to improve input decisions. His aim was to use grain yield and quality data to create management actions for the following crop. Again, these priorities aligned with these Managers' responsibilities as clarified in the exit interview. Manager 1 drove the seeding equipment and harvester, while Manager 2 was in charge of spray application.

Table 7.3

Summary of Responses by Team Member to 'Which Process Would You Like to Digitise First and Why?'—Team 3

Team 3 role	What	Why
M	Collection, storage and integration for further use the harvest and GPS guidance data	To save time, improve accuracy and use data
Ma	Digitisation of loading sprayer	To improve OH&S, record and stock management
O	Full digitisation of chemical handling, storage and stock	To improve efficiency, accuracy and OH&S
A	Left the research	

Note. M = Manager 1, Ma = Manager 2, O = Operator, A = Trusted Adviser, GPS = Global Positioning System, OH&S = occupational health and safety.

7.1.4 Team 4

Improving efficiency was the common thread in the process changes nominated by Team 4 (Table 7.4). Three members of the Team (Manager 2, the Operator and the Trusted Adviser) proposed changes that would improve efficiency. The priorities of the Managers, Trusted Adviser and, in part, the Operator, could be achieved with the tools and technologies reported in the survey as being used: Agworld for production records; and GPS and autosteer (Trimble Ag Solutions) for spatial management. Their choices indicated the team members' lack of digital sophistication and that current tools were not fully utilised. Indeed, in response to the survey question, ‘what is holding you back from digital investment?’, Manager 1 stated ‘lack of knowledge and understanding how to use’; and Manager 2, ‘not sure what’s out there or what will be useful—don’t have time to investigate’.

The responses to the video question also suggested that inventory control could be a problem experienced in this business, both from the position of having inputs available, and knowing the quantity, quality and location of hay bales, a major income stream for this team.

Table 7.4

Summary of Responses by Team Member to ‘Which Process Would You Like to Digitise First and Why?’—Team 4

Team 4 role	What	Why
M	Nitrogen management on a spatial basis, matched to soils	Improve nitrogen use efficiency, productivity
Ma	Digitise farm maps and records, including weather and spray records	Uniform access to records at all locations, improve efficiency, accuracy and data recording
O	Spray records and hay stocks	To make life simpler
A	Linking chemical recommendations to chemical stock on hand and purchases required	To know stock before purchasing more

Note. M = Manager 1, Ma = Manager 2, O = Operator, A = Trusted Adviser.

7.1.5 Team 5

A production focus was taken by Team 5 (Table 7.5). While the processes selected for digitisation differed, reasons had a similar end point, which was to improve productivity through maximising water use. The Manager wanted to locate clay in the soil profile to know which incorporation technique to use: addition of clay to sandy soil helps increase the amount of water stored for crop growth. The operator and Trusted Adviser wanted a better understanding of the crop’s needs and the potential of the crop in relation to current and forecast conditions, to enable nitrogen and other inputs to be better matched to the crop and season. Although the Operator and the Trusted Adviser had the same aim, their descriptions of need and reason were quite different, with the Operator providing neither frequency of measurement nor the need for it to be on a spatial basis. However, the Operator clearly stated the management decision that would be supported if this process were digitised.

Table 7.5

Summary of Responses by Team Member to 'Which Process Would You Like to Digitise First and Why?'—Team 5

Team 5 role	What	Why
M	Detailed digital soil map to depth, especially to identify clay location	To help identify where to delve and deep rip, management of soil variability
O	Real-time crop nitrogen levels, linked to crop growth and current and forecast soil moisture	To improve appropriateness of nitrogen decisions
A	Spatial yield potential at any point in the season.	To gain a better understanding of the relationship between late NDVI, yield and soil's finishing ability in different seasons

Note. M = Manager, O = Operator, A = Trusted Adviser, NDVI = Normalised Difference Vegetation Index.

The lack of a single team nominating a single process as the priority for digitisation emphasised the importance of all members of a family farming business being involved in the selection of digital priorities and their implementation. Across the teams several themes regarding digitalisation of processes were revealed from the responses.

These were:

- systems to enable data interoperability along the workflow, especially in relation to chemical usage and stock control
- data collection and integration on factors that drive production and profitability
- remote access to monitor assets and support business administration processes.

7.2 Video 3

Video 3 theme: ‘The role of the change captain’

Video 3 questions: ‘Who would you nominate as change captain? What roles do you see for others in your team?’

Change management theory identifies the nomination of a single change captain and the right choice of change captain as essential for the success of a change project (Hiatt, 2006). The questions with Video 3 aimed to explore how the farming teams viewed the participation of their team members in guiding and achieving digital change.

Team members were asked to nominate their change captain, and to explain the participation of each team member in the change via their response to the question, ‘How important will each team member be in terms of hands-on action or general support in making the change occur and stick?’. For this question, the following options were provided in a table that was emailed to each participant, requiring the following response options: not important, important, very important or not sure. Video 3 encouraged team members to think of their choices in relation to the process they had proposed for change following Video 2. Responses to the two questions as detailed by team members are given in Table 7.6. These responses illustrate consistency in the choice of change captain in Teams 2, 3 and 4 and inconsistencies in Teams 1 and 5. Team 3 Operator did not specify a captain, stating it would be a ‘team effort'. The Trusted Adviser in Team 1 was transitioning back to the family farm and considered himself the most appropriate captain for digital change, whereas the other Team 1 members nominated the Manager. All members of Team 2 that responded nominated the same Manager as change captain, but Manager 2 in this team failed to respond to these questions. All Team 4 members nominated the Manager as the change captain (including the Manager himself). In the surveys, this Manager had stated a lack of knowledge and understanding of digital and that their management style was to have the final say. These two factors could create conflict in the teams' adoption process, but the latter left little option for the team to select an alternative change leader. Despite the common goal for change expressed by Team 5, members varied in their opinions about who should lead the change.

Because these responses were aligned to each individual's priority for change, comparison between the importance of different roles was difficult. For some team members, the Trusted Adviser was seen as very important; in others, not important. The external Trusted Advisers in Teams 2 and 4 saw themselves as very important in supporting the change, while in Team 5 they nominated themselves as change captain but were unsure of the role they would play in hands-on support for the change. This confusion was further expressed by seven of the 17 participants who provided more detailed email responses rather than just completing the multiple choice table provided. These comments included:

> Team 1: 'Tricky applying this to future technology and not something concrete that is already developed'.
>
> Team 2: 'Managers and employees are both very important to the success of this [change], with outside parties being available to help out as needed'.
>
> Team 3: 'Initially jobs will be split and assigned as per individual's areas of expertise'.

Team 4: ‘I believe that everyone involved in using the proposed changes is very important for hands-on actions as well as supporting the change’.

Team 5: ‘I found this a little bit confusing, but our usual process is that together we will discuss all aspects of decision making’.

Several comments referred to working together and different members of the team taking responsibility for aspects of the change. Although responses did align with the survey questions on management style and team inclusivity in decision making, they also illustrated that the concept of needing one person to guide and take responsibility for the completion of the change was not a familiar one to which they subscribed.

Table 7.6

Team Member Nominations for Change Captain and Ranking of Importance of Team Member in Implementing or Supporting the Change

Team 1 role	Captain nominated	Hands on M	Hands on O	Hands on A	Support M	Support O	Support A
M	M	Important	Not important	Very important	Very important	Important	Important
O	M	Very important	Not important	Important	Very important	Important	Very important
A	A	Not important	Very important	Important	Very important	Not important	Important

Team 2 role	Captain nominated	Hands on M	Hands on Ma	Hands on O	Hands on A	Support M	Support Ma	Support O	Support A
M	M	Very important		Important	Very important	Very important		Important	Very important
Ma	No response								
O	M	Very important	Very important	Very important	Not important	Very important	Very important	Very important	Not important
A	M	Very important	Very important	Important	Important	Very important	Very important	Very important	Very important

Team 3 role	Captain nominated	Hands on M	Hands on Ma	Hands on O	Hands on A	Support M	Support Ma	Support O	Support A
M	M	Very important	Very important	Very important	Not important	Very important	Very important	Very important	Not important
Ma	M	Very important	Very important	Very important	Not important	Very important	Very important	Very important	Not important
O		Very important	Very important	Very important	Not important	Very important	Very important	Very important	Not important
A	Left team								

Team 4 role	Captain nominated	Hands on M	Hands on Ma	Hands on O	Hands on A	Support M	Support Ma	Support O	Support A
M	M	Important	Important	Important	Important	Important	Important	Important	Important
Ma	M	Very important	Very important	Very important	Important	Important	Important	Important	Very important
O	M & Ma	Important	Important	Important	Important	Important	Important	Important	Important
A	M	Very important	Very important	Important					Very important

Team 5 role	Captain nominated	Hands on M	Hands on O	Hands on A	Support M	Support O	Support A
M	O	Very important	Very important	Important	Very important	Important	Important
O	O	Very important	Very important	Important	Very important	Important	Important
A	A	Important	Very important	Not sure	Important		Not sure

Note. Video 3 Question: ‘How important will each team member be in terms of hands-on action or general support in making the change occur and stick?’, M = Manager 1, Ma = Manager 2, O = Operator, A = Trusted Adviser.

7.3 Video 4

Video 4 theme: 'The art of agile management'

Video 4 question: 'What is stopping you from making the change proposed in response to Q2?'

Relative estimation is a technique used in agile management to help rapidly prioritise complex tasks. Most farmers, without their knowledge of the term, engage in agile thinking, as reiterated by a Team 5 member in the exit interview: 'Agile thinking is entrenched in our decision making. We are constantly readjusting plans depending on a range of factors'.

Video 4 was designed to introduce the agile management approach of relative estimation to support step 3, the evaluation stage of the adoption framework. Question 4 was posed in relation to their unconstrained process change nominated after video tutorial 2. In Video 4, Fibonacci numbers were described as a scale that can be used to provide priority and scale.

Participants were asked to rank six factors limiting change that were identified from the responses to the survey instrument. The option to add as many other limiting factors as desired was also provided. Using a Fibonacci scale, a score of 1 had the least negative impact on them making the change. Unfortunately, the relative estimation example did not use a pure Fibonacci scale, creating confusion for respondents. This resulted in five participants using a simple 1–5 ranking system and the remainder using a scale that illustrated order and scale of the barriers to change. However, the results still provided an indication of the factor considered the least important reason or barrier to making the change and that considered the most (Figure 7.1). No consistency in responses was found within or between teams. Lack of awareness of solutions was rated as a major barrier by seven participants but also as a non-issue by four respondents. Three respondents rated multiple items with their largest score; hence the different size of the total number of responses by size. One participant failed to respond to this question because of a problem with their email account. Lack of time to research and implement the change was the next biggest barrier and was rated by many as their second largest barrier to implementing the proposed digital change. At least one participant from each team provided additional statements about issues that were holding them back form making the change. These statements included:

> Team 1: 'Circumstances had changed in management'. (During the exit interview they reported some health issues that had positively initiated some succession planning and changes in roles for the team members).
>
> Team 2: 'Poor integration of current platforms used on the farm and lack of data standards'.
>
> Team 3: 'Paying for software that will become redundant' and 'concern over 'making the wrong decision on which software to buy in the first place'.
>
> Team 4: 'Fear that the change will be negative.'
>
> Team 5: 'The approach I take is, that to get major change you need many different people heading in the same direction. This is a major time constraint, and it may take 10 years for this to happen. I'm a great believer in a "point in time" that is right to engage the broad base of people to make major change. In summary, you may have an idea/concept but to get change occurring it is all about timing and this requires patience.'

These statements provided greater insights into a wide range of factors that were limiting digital adoption on farm. The use of the videos after the surveys had helped build the participants' engagement in the research so they freely provided more in-depth responses.

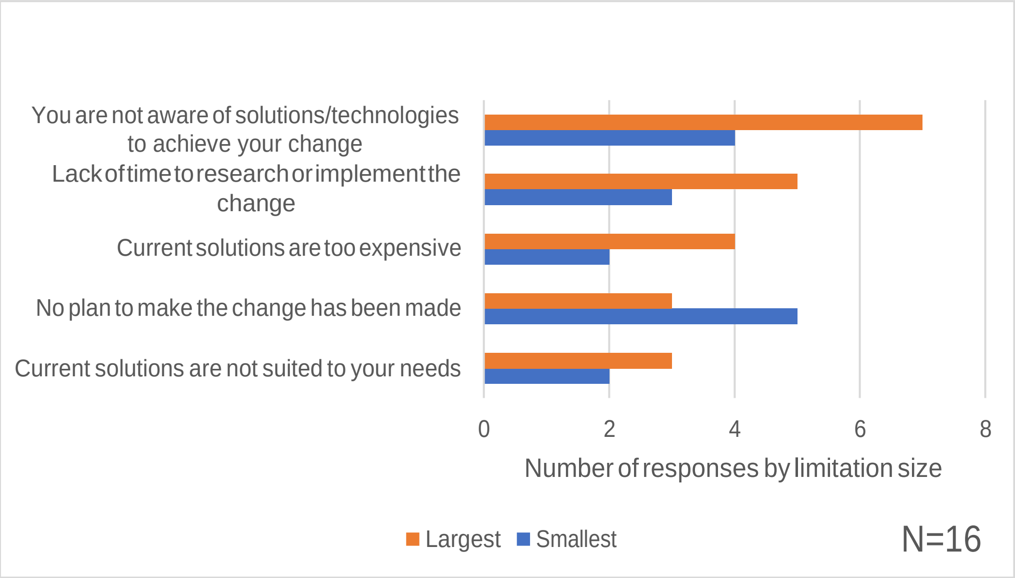


Figure 7.1

Respondent Ranking of the Factors Preventing the Change Proposed in Response to Question 2

7.4 Video 5

Video 5 theme: ‘Data flows and interoperability of datasets’.

Video 5 question: ‘Does this breakdown represent the core and focus management areas for your business?’

For a process to be digitised requires data to be able to flow between different technologies. To better understand current and required data flows in the mixed farming business the open responses to the question in Videos 2, 3 and 4 were uploaded to the qualitative data analysis platform NVivo 12. The objectives of using word analysis were to:

- identify the key activities, areas and workflows of the mixed farming business that would be associated with digitalisation of data and digitisation
- identify the words used by the teams to help populate the DPM tool with appropriate and familiar terms.

A word cloud of the top 100 words over three letters and clustered by stem words was produced (Figure 7.2). The first analysis resulted in the word ‘management’ dominating the cloud. As management was considered an overarching term associated with all activities it was removed from the analysis as were the researcher’s questions. The word cloud was added to the resources used to develop the components, subcomponents and situation statements for the DPM. Although the cloud was dominated by the words ‘soil’, ‘data’ and ‘change’, it was often the less used words such as ‘inventories’, ‘planning’, ‘organisation’ and ‘maintenance’, for example, that helped direct the development of the focus activities (Figure 7.2).

Figure 7.2

Word Cloud of Responses Gathered from Videos 2–4

Note. Top 100 words over three letters by stem words. Names and Product Brands and researcher’s questions excluded.

In Video 5, the researcher shared with participants two of the processes that had been proposed in response to the question in Video 2 as the first to be digitalised. These were the integration of individual sheep data from key profit drivers (Team 1) and full digitisation of chemical handling, storage and stock (Team 3). The latter was extrapolated to include compliance reporting. The data flows and software interoperability requirements illustrated in these examples were highlighted in Video 5. Following the explanation of the data flows in these digitised processes a simplified representation of the business data needs was presented (Figure 7.3). The dryland mixed farming business was broken down into four core functions and 17 focus activities. Each focus activity represents potential data sources or uses that support the core function. The focus activities within a core function represent the data sources required to be interoperable for the digital functioning of that core.

Based on these core and focus areas, the data types were aligned with the digitised process proposed after Video 2 (Table 7.7). For many processes, data from multiple focus activities might be required; some would be ‘essential’ (primary) and some ‘useful’ (connected). Consequently, primary and connected focus activities were associated with each proposed digitised process aligned with the hypothesis that to achieve digitised processes, data in all software used for primary focus activities listed for the process change workflow would need to be interoperable. With the information regarding their data flow requirements for their process change and the descriptions in the video, the question regarding the appropriateness of the core functions and focus activity structure was posed. Each team received their section of Table 7.7 with the link to Video 5, to help contextualise the concept of data flows from tasks and processes to focus activities.

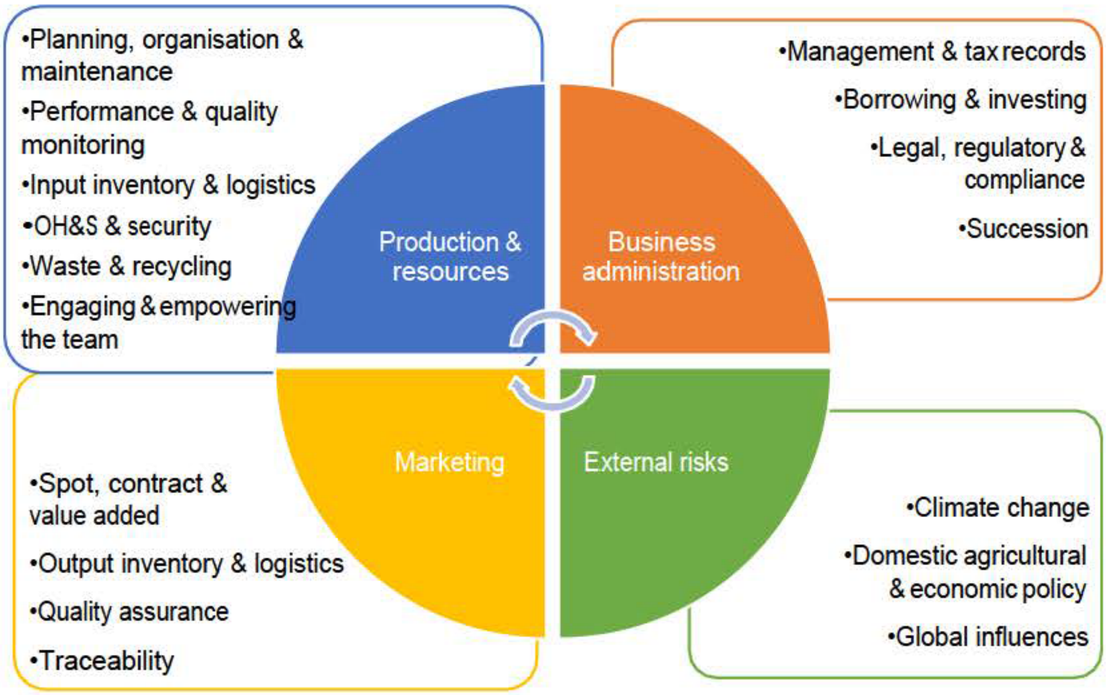


Figure 7.3

Initial Framework of Core Functions (Solid Blocks) and Focus Activities (Clear Blocks) Based on Data Sources and the Potential Need for Interoperable Data Between all or any of the Four Functions (Arrows)

Feedback received from the teams following Video 5 was used to modify the core business functions and focus activities (Figure 7.4). All teams acknowledged the influence of factors outside the farm and the need to be aware and vigilant about these factors in relation to strategic and seasonal management decisions. However, external risks were not viewed as a core function area for two reasons. They were considered beyond the management control of the business and—unlike weather, which is also beyond the control of the business—they did not include data pools that would need to be integrated into a workflow.

Table 7.7

Data Flows from Primary and Connected Focus Activities Required to Support Process Change Proposed After Video 2, by Team

Team 1	What	Primary focus activities	Connected focus activities
M	Real-time, remote identification of individual sheep	Performance & quality monitoring OHS & Security	Management & tax records, in & out inventories, trace ability
O	Remote monitoring of troughs & feeders	Performance & quality monitoring	Waste & recycling
A	Integration of individual animal data from key profit drivers—wool weight, micron & body weight	Performance & quality monitoring	Management & tax records, in & out inventories, traceability

Team 2	What	Primary focus activities	Connected focus activities
M	Data to understand returns at a paddock & then spatial level Full automation of the creation of input prescriptions at seeding & top dressing & integration with yield data	Management & tax records Performance & quality monitoring	Planning, organisation & maintenance, inventories in & out, legal, regulatory & compliance, spot, contract & value-added markets, waste & recycling
Ma	Lifetime individual sheep tracing & association of data relating to profit drivers; e.g., days not pregnant, wool & meat weights/yields Automated establishment of productions groups & linked to virtual fencing	Performance & quality monitoring	Planning, organisation & maintenance, management & tax records, waste & recycling
O	Digital weed control for accuracy & chemical inventory	Input inventory & logistics	Planning, organisation & maintenance, management & tax records, legal, regulatory & compliance, waste & recycling
A	Detailed, digital soil & landscape maps	Planning, organisation & maintenance	Performance & quality monitoring, management & tax records

Team 3	What	Primary focus activities	Connected focus activities
M	Collection, storage & integration for further use of harvest & GPS guidance data	Performance & quality monitoring	Management & tax records, traceability
Ma	Digitisation of loading sprayer	Input inventory & logistics, OH&S & security, legal, regulatory & compliance	Planning & organisation, performance & quality monitoring management & tax records, waste & recycling, borrowing & investing
O	Full digitisation of chemical handling, storage & stock	Input inventory & logistics, OH&S & security, legal, regulatory & compliance	Planning & organisation, performance & quality monitoring management & tax records, waste & recycling, borrowing & investing
A	Retired for personal reasons		

Team 4	What	Primary focus activities	Connected focus activities
M	Nitrogen management on a spatial basis, matched to soils	Planning, organisation & maintenance Performance & quality monitoring	Management & tax records, input & output inventories & logistics
Ma	Digitise farm maps & records, including weather & spray records	Management & tax records	Planning, organisation & maintenance, performance & quality monitoring, input & output inventories & logistics, legal, regulatory & compliance, quality assurance, spot, contract & value-added markets
O	Spray records & hay stocks	Input & output inventories & logistics	Management & tax records, performance & quality monitoring
A	Linking chemical recommendations to chemical stock on hand & purchases required	Input & output inventories & logistics	Management & tax records, legal, regulatory & compliance, quality assurance

Team 5	What	Primary focus activities	Connected focus activities
M	Detailed digital soil map to depth, especially to identify clay	Planning, organisation & maintenance	Performance & quality monitoring, management & tax records
O	Real-time crop nitrogen levels, linked to crop growth & current and forecast soil moisture	Planning, organisation & maintenance, performance & quality monitoring	Management & tax records, input & output inventories & logistics
A	Spatial yield potential at any point in the season	Planning, organisation & maintenance, performance & quality monitoring	Performance & quality monitoring, input & output inventories & logistics, spot, contract & value-added markets

Several participants suggested that focus activities should be moved to alternative core functions, or combined. These changes were shared with all Managers, and Figure 7.4 illustrates consensus regarding those changes. Connectivity was added to business administration because consideration of connectivity options was required as it was considered the enabling function for data flows across the business. Data relating to OH&S were linked with compliance and moved from production and resources to business administration. Similarly, engaging and empowering the team was reallocated and called employee records. Waste and recycling were not considered linked to data flows and were deleted, while variation management and the decision-making unit were added to the core function production and resources.

Teams agreed that data would need to flow between core and focus areas; however, to secure tenure of data and control cost it was felt this sharing should be controlled by the farming business and not the suppliers of software. This was reiterated in the exit interviews.

> Team 1: 'He [A] has been looking at AgriWebb but he is still not convinced. It is so expensive'.

Team 2: ‘You want your data to be accessible, and make it possible to pivot to new businesses, so you are not locked in’.

Team 3: ‘We had a preliminary look at the Figured program, but that needed Agworld and Xero to talk to Figured and one of the links was broken so we didn’t bother’.

Following several rounds of participant feedback and restructuring of the framework, especially by Managers and Trusted Advisers, the following breakdown of core business functions and focus activities that would be associated with specific data types was developed (Figure 7.4). The core business functions became the components, and the focus activities became the subcomponents in the DMT, which is described in Chapter 6. A worked example of a process evolving from manual to digitally transformed and the place of the core and focus activities is in Appendix H.

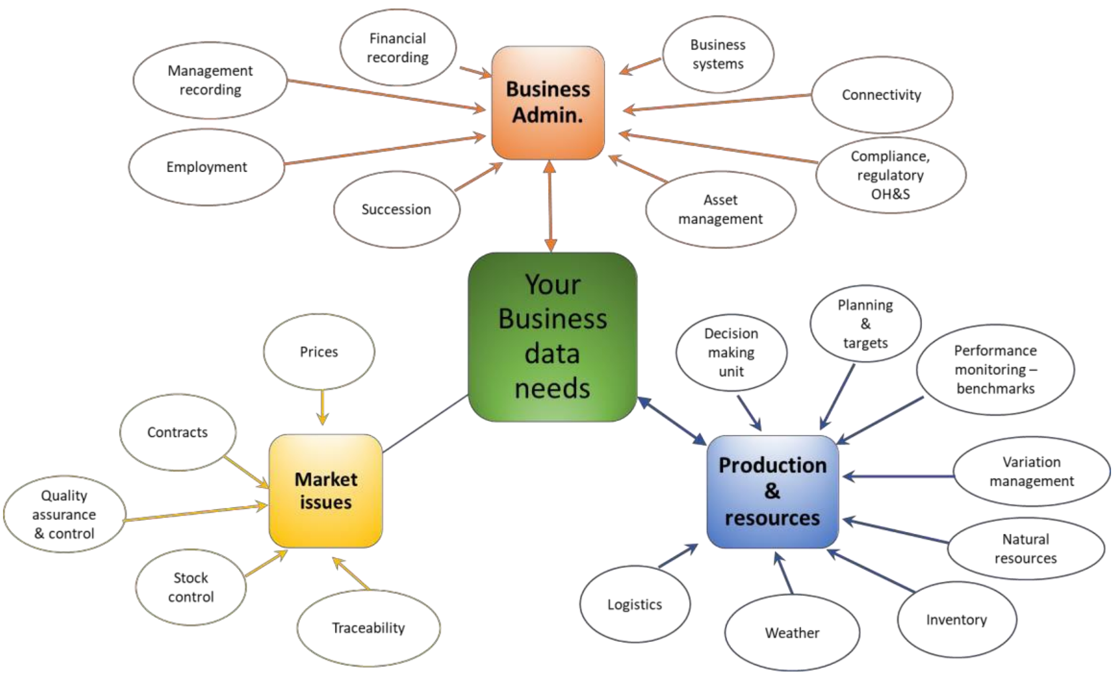


Figure 7.4

Core Business Functions and Focus Activities Relating to Data Flows

Note. Each focus activity can consist of one or more tasks and combine with other focus activities to create processes.

7.5 Summary Chapter 7

The video tutorials proved a productive method for conveying and gathering information with the teams. In many instances, team members provided more detailed responses than requested, which indicated commitment to the process. The value of the team approach was evident in the clear differences in digital priorities proposed by each team member. A mixture of business and production processes were proposed for digital change, and these ranged from simple to complex.

Confusion regarding the current position and inconsistency of ambition between members of the family Farm Business Team in relation to the adoption of digital solutions was identified by the surveys and reinforced in the video feedback. Inconsistency and some confusion were also reported around the concept of the change captain in relation to implementation in a family farming business, as well as the importance of different roles in achieving digital change. The inconsistency in responses to Videos 2 and 3 highlighted that an adoption framework could offer a way to work through these differences to create a consistent approach to a change. However, the teams reported lack of a plan to make change as the smallest reason preventing them from changing. This finding must be viewed in relation to the most influential factors preventing change, which were reported as lack of knowledge, confidence and time.

This theme of individuality and how it could be embraced to support improved uptake of DA by a family farming business, as identified in Chapter 6, was illustrated in the responses to the open questions. The need to ensure all team members are working to a common goal, not one of personal choice, underpins the development of the evaluation tools for people and business process. Without knowledge of the current situation, skills, processes and ambitions it is difficult for a business to have a clear and direct path for improvement and change.

The responses from the three data collection tools—surveys, semi-structured interviews and video tutorials—were used to populate the DKSA and the DMT with realistic and relevant statements. The responses and feedback from Videos 2 and 4 were specifically used to support the identification of the components and subcomponents for the DMT. The process of iterative development and assessment of the evaluation tools is presented in Chapter 8.

Chapter 8: Results and Analysis—

Evaluation Tools

In this chapter the results and analyses from the DKSA tool and DMT are presented. Participants' responses to the evaluation tools and exit interviews assisted in informing the answer to the second part of sub-question RQ2: *how could this be supported by a change management approach?*

The strengths and weaknesses identified by the evaluation tools would be part of the considerations when using the Change Guide for a specific digital change. The structure and population of the tools was assessed using the Delphi method with the evolution of the tools presented in this chapter. These results are supported by quotes from the exit interviews to provide a clear picture regarding the participants' perceptions of the evaluation tools and the development process.

Descriptive statistics are used to report the qualitative objects of the tools as quick to use and to provide a relevant maturity score. The aim of combining the qualitative and quantitative results is to demonstrate the appropriateness of the structure, content validity and scoring of each evaluation tool
(see Appendices F and G).

8.1 The Digital Knowhow Self-assessment Tool

Using the Delphi method to gain consensus on the content and tool structure, three iterations of the DKSA tool were tested by all 17 remaining participants in the five teams. The following sections describe the results from each of the Delphi testing rounds and how these were used to improve the content validity. The three versions of the DKSA tested were named Alpha, Beta and Final. The results are reported against the aims of the Final tool, to:

1. provide a quick, reliable and valid method to quantify digital knowhow and monitor change
2. create a self-assessment process suited to multiple roles within a family farming business
3. establish a digital knowhow maturity score aligned to a stage gate.

Qualitative assessment using feedback from the Farm Business Team members was used to address the first two aims. Descriptors such as ‘useful’, ‘easy to use’ and ‘quick’ were the types of positive affirmation sought to validate the DKSA. Descriptive statistics were used to assess the closeness of the relationship between the capability and validation scores, as well as individuals’ perspectives on their scores, to meet aim 3 above.

8.1.1 DKSA Structure—Alpha

The Alpha version contained 84 statements. There was one statement for each of the four stage gates, for each of the seven skills, for each of the three characteristics (Figure 8.1). Only the answers ‘yes’, ‘no’ or ‘I don’t understand’ were allowed for each statement. The survey was designed so that respondents were not aware of the components, subcomponents and stage gates behind the design. The order of statements was from those relevant to the minimal stage gate to those relevant to the initiating stage gate, by component and subcomponent. Every participant saw the same statement order; there was no randomisation of presentation order.

All 17 participants completed the Alpha version and provided feedback (Table 8.1). Because of the different methods of receiving the survey link, not all answers could be attributed to a team member. Several participants stated that it was quick and easy to complete, although one was unsure how this information could be put to use. All reported that it took less time to complete than the platform recorded, suggesting they perceived it to be quick to complete. The automatic time recording continued for the time for which the survey was open, irrespective of activity, which also accounted for differences between reported and recorded completion times. The longest completion time reported by a participant was 15 minutes; and by the platform times, 21 minutes. The mean completion time recorded by participants and the platform timer was 10 minutes and 13 minutes, respectively.

All feedback was positive but four respondents requested a less definitive option between ‘yes’ and ‘no’; for example, ‘maybe’ or ‘sometimes’ to indicate lack of discreteness in the statement. ‘Yes’ responses received a score of 1 and ‘no’, a score of 0. Of the 84 statements, 13 (15%) were answered ‘I don’t understand’, by at least one participant, representing 41% of participants.

Table 8.1

Feedback and Completion Times for the Alpha Version of the DKSA

Team number and role identifier	Comment	Time (minutes)	
		Recorded by software	Reported by participant
	Easy to answer	8	5
	Good	12	10
	Some questions did not apply to me	8	8
	Ok; some questions need a fence-sit option—sometimes or maybe	15	10
	Good	9	<10
	not too hard	21	10
2M	Okay I guess. I needed a ‘sometimes’ or ‘maybe’ box	10	10
4A	Easy	10	5
2Ma	How will this process help me?	12	15
1A	Most of the questions were easy to follow with a few I didn’t understand with the integration of datasets; I don’t find enough time to analyse all of the data and I know this is something I am going to have to rectify but if more of the data was integrated in one system this will be made a lot easier	29	15
2A	Easy	9	5
1O	Positive—simple to work through the survey	9	10
3M	A ‘not sure’ option would be good.	9	15

Team number and role identifier	Comment	Time (minutes)	
		Recorded by software	Reported by participant
4M	Ok, maybe not enough options to choose from on some questions	9	10
	Easy enough; shows how little we know or know how to use technology	9	
	Easy	21	
	Quick and easy	15	10
	Mean completion time (minutes)	13	10

Note. Because of participants responding to different links to the survey, participant indicator was not always identified in the Alpha version. M = Manager 1, Ma = Manager 2, O = Operator, A = Trusted Adviser.

8.1.2 DKSA Evolution of Alpha to Beta Version

After reviewing the responses and feedback to the Alpha version, 15 statements were reworded to improve clarity, and circulated to all in the Beta version. The Beta version provided the opportunity to add comments on the statements, and contained 20 validation statements grouped into five blocks. Validation questions had a total maximum score of 84. A basic analysis process of the Beta version summed 'yes' answers and calculated these as a proportion of total answers provided. In addition to total scores, the analysis of responses was completed by skills and by characteristics. Scores from the Beta version were compared with scores for the validation questions by individual. This analysis highlighted a major design limitation of the Alpha and Beta versions: the 20 statements in the validation questions were not discrete for the seven skills and three characteristics. This meant that the relationship between the tool score and the individual's perception of their digital capability based on responses to the validation questions—a proxy for the tool's appropriateness with a small sample—could only be examined by total score and not by components and subcomponents.

8.1.2.1 DKSA—Final Version Structure

The Final version of the DKSA contained 62 sections, 38 of which were statements requiring ‘yes’, or ‘no’ answers. Of these, 9 also had a ‘not sure’ option. A further 11 statements required ‘true’, ‘false’ or ‘not sure’ answers. The remaining 13 responses used image selection, multiple choice or slider rating bar formats. Five were validation questions, and four related to the survey. Thirteen sections required multiple responses, including three of the validation questions. The total number of responses required for the Final version was 116, not including the four feedback questions.

The survey structure was the same as for the Alpha and Beta versions, with statements flowing from minimal to initiated. Validation questions for knowledge and attitude were located in the main survey. For attitude and knowledge these were multiple choice. Three questions to further validate the three characteristics, as well as the participants’ self-assessment of their ability for each of the seven skills, used a 10-point Likert scale ranging from 0 = ‘very poor’ to 10 = ‘excellent’.

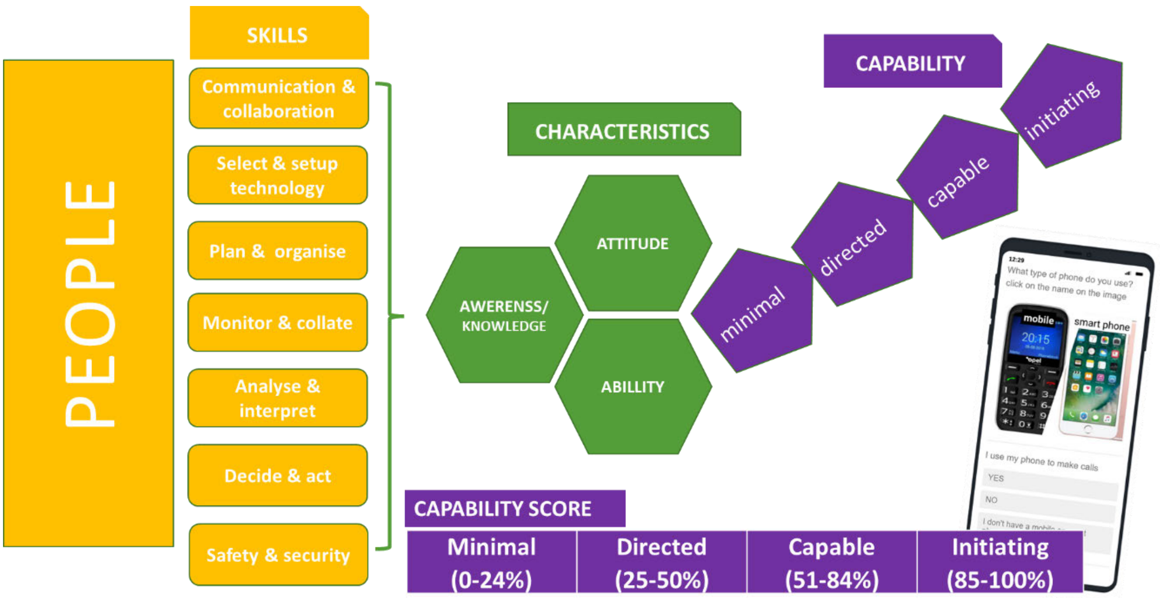


Figure 8.1

The Components of the DKSA Tool and Scores

8.1.2.2 DKSA Feedback and Completion Time

The perception by all participants, irrespective of role, was that the tool was quick and easy to complete; thus meeting part of aim 1, as well as aim 2 for the tool, as outlined in Section 8.1.

All participants completed the Final version and reported preferring this version of the DKSA tool. The mean completion time recorded by the platform increased by 20 minutes to 33 minutes and by the participants from 10 minutes to 16 minutes. The shortest completion time reported by participants was 5 minutes and the longest 30 minutes. As with the Alpha version, the software recorded uninterrupted activity time because the timer continued while the incomplete survey remained open.

Only two people provided additional comments, being, ‘quick and easy to use’ and ‘Sometimes not just yes/no answer might be comfortable with one example but not all’. The following statement from the exit interviews highlighted a potential issue with the use of the term ‘knowledge’ in the evaluation tools and the framework:

> Team 3: ‘One thing I would like to suggest with the knowledge is the in-depth versus superficial knowledge. I [M] know that diesel goes in an engine and smoke comes out, and [Ma] knows how it works. With computing it’s the other way around’.

8.1.2.3 DKSA—Final Version Scores

An individual’s total score for the tool was compared with their validation score, expressed as a percentage of the respective maximum scores (Figure 8.2). The mean difference between the total percentage score from the DKSA and the validation sections was +1%, with a range of +10% to −9%. Nine scores from the tool were higher than the validation score, one equal and seven lower. Assuming the individual’s perception of their digital knowhow in relation to the validation statements was accurate, the mean score for the tool was a small overestimate of digital knowhow. This use of validation by self-reporting is not without limitations but as the aim of the tools is to provide an indication, rather than an absolute result the comparison with their perception of their own ability was considered acceptable.

To further evaluate the appropriateness of the score, validation scores for skills and characteristics were investigated. The structure of the tool meant that the sum of either the skills scores or the characteristics scores was equal to the total score. Consequently, an individual's total percentage score could be compared with their percentage validation score by skills and characteristics. The maximum scores for each component and subcomponent used to calculate the percentage scores are listed in Table 8.2.

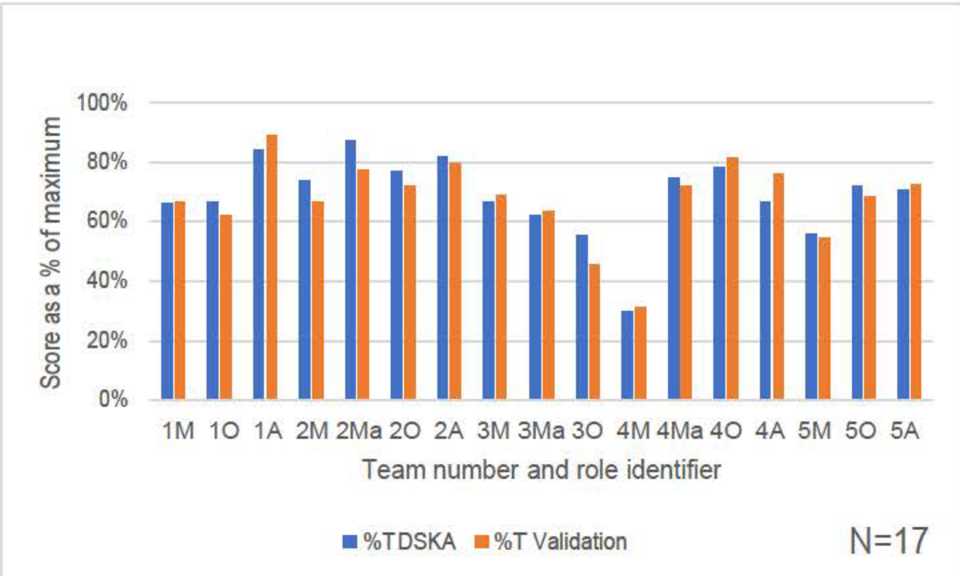


Figure 8.2

Scores by Tool and Validation Sections as Percentage of Maximum Score—All Participants

Note. Role identifier M = Manager, Ma = 2nd Manager in same team, O = Operator, A = Trusted Adviser.

Table 8.2

Maximum Possible Scores for the DKSA and for Validation by Total, Skills and Characteristics

		DKSA	Validation
	TOTAL	360	167
Component—skills	Communicate and collaborate	47	10
	Select & setup technology	55	10
	Plan & organise	55	10
	Monitor & collate	48	10
	Analyse & interpret	52	10
	Decide & act	48	10
	Safety & security	55	10
Subtotal		360	70
Subcomponent—characteristics	Knowledge	34	32
	Ability	46	10
	Attitude	280	55
Subtotal		360	97

The range of variation between the total and validation scores for skills was +19% to −6%, a mean overestimate of +4% by the DKSA (Figure 8.3). Eleven scores from the DKSA were higher than the skills validation, two were neutral and four were underestimates. For the characteristics the range was +9% to −9%, resulting in a mean overestimate of +1%. Eight scores were overestimates, one was neutral and eight were underestimates. Overestimation of the DKSA score was noted especially for participants that had high scores in the questions with ranked scoring using a Fibonacci scale. Based on the small number of participants, the mean variation between the scores from the tool and the validation questions suggests the scoring system provided a representative indication of an individual's skills and characteristics in relation to DA.

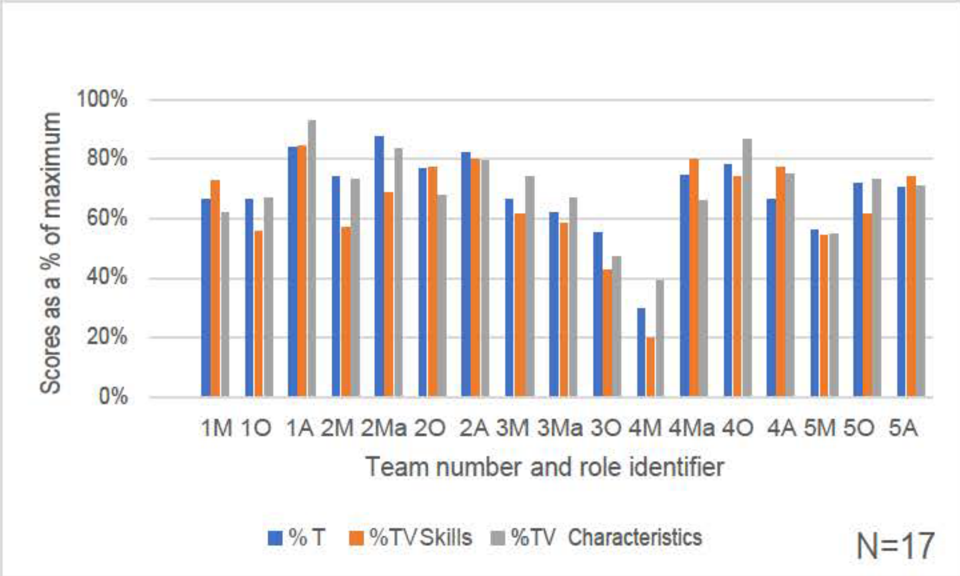


Figure 8.3

Scores by Total for DKSA versus Total Validation (TV) Score by Skills or Characteristics as a Percentage—All Participants

Note. Role identifier M = Manager, Ma = 2nd Manager in same team, O = Operator, A = Trusted Adviser.

8.1.3 Maturity Scoring

To use the DKSA to assess current and changed digital knowhow, a participant's score needs to be related to a stage gate. An equal quartile scoring system was applied to the four stage gates, however, the variation in scoring by question type required the scores presented in Figure 8.2 to be weighted to enable comparison. This reduced the individual's total score (Figure 8.4). Based on the stage gates developed for this research (Section 4.7.1.3) the target score for employees in a digital workplace is above 50%. The maturity scores in Figure 8.4 are representative of the final output of the DKSA and how it can be used to compare scores between team members.

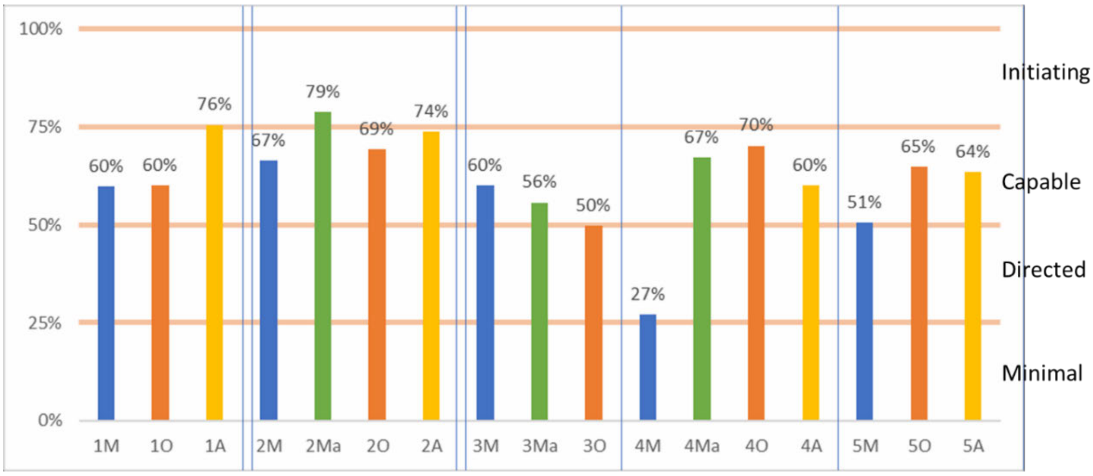


Figure 8.4

Maturity Score from DKSA by Participant

Note. Minimal = 0–25%, Directed = 26–50%, Capable = 51–75%, Initiating 76–100%. Role identifier M (Blue) = Manager, Ma (Green) = 2nd Manager in same team, O (Orange) = Operator, A (Yellow) = Trusted Adviser.

The contribution of the components and subcomponent scores to the individual's total score are illustrated for each team in Figure 8.5 to Figure 8.9. The sum of an individual's percentages for all skills and all characteristics is 100%. Comments in the exit interviews that related to the team's thoughts on the DKSA are presented below the figure in each case. These also support the answer to the question posed in Video 6: *How well do you think your score and the definition reflect your digital knowhow?* The feedback supports the appropriateness of the DKSA as a tool for rapidly quantifying digital competency of team members in various roles, from which strengths and weaknesses in skills and characteristics can be gauged.

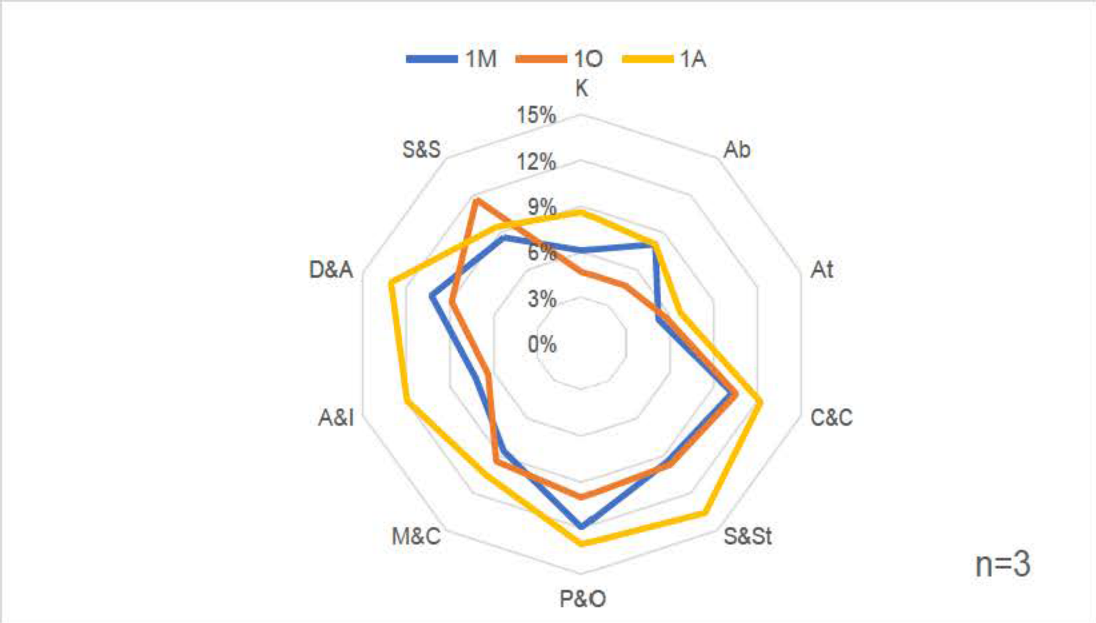


Figure 8.5

Percentage Contribution of Skill and Characteristic Scores to Total Maturity Score by Role—Team 1

Note: K = knowledge, Ab = ability, At = attitude, C&C = communicate and collaborate, S&St = select and setup, P&O = plan and organise, M&C = monitor and collate, A&I = analyse and interpret, D&A = decide and act, S&S = safety and security. Role identifier M = Manager, Ma = 2nd Manager in same team, O = Operator, A = Trusted Adviser.

The following quotes from the exit interview with Team 1 illustrate the benefit they gained from having a digital capability score that can be compared with that of other team members:

> 1M: '[DKSA] helps confirm who is better at what, and that I am not as far behind as I thought I was'.
>
> 1O: 'Which is true, we would think that'.
>
> 1M: 'Yes we would, we probably would. We want to know their strengths and make sure they were being valued. We want to make sure they knew what was

going on. It [DKSA] would be a two-way street, we would also be able to see what we expected in them [employees]'.

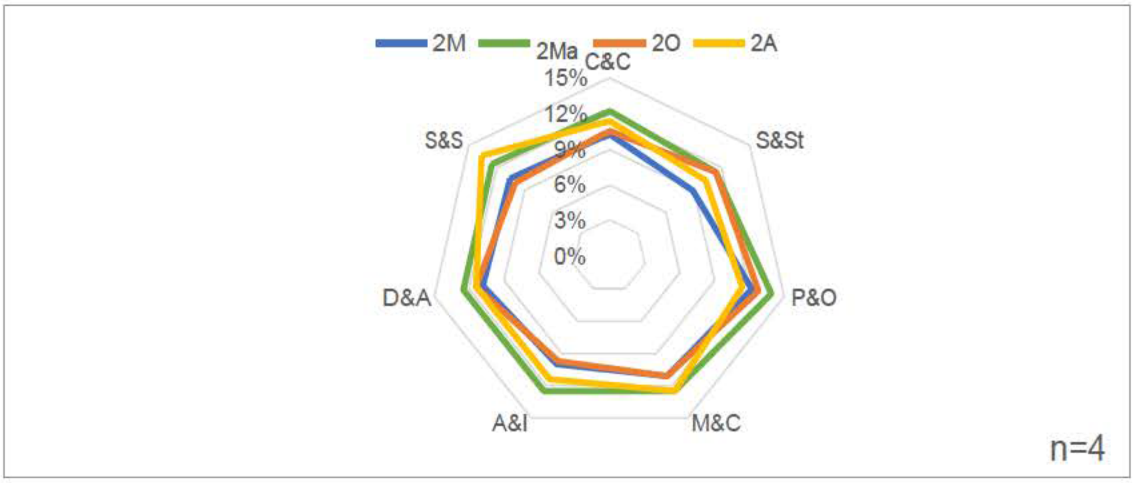


Figure 8.6

Percentage Contribution of Skill and Characteristic Scores to Total Maturity Score by Role– Team 2

Note. K = knowledge, Ab = ability, At = attitude, C&C = communicate and collaborate, S&St = select and setup, P&O = plan and organise, M&C = monitor and collate, A&I = analyse and interpret, D&A = decide and act, S&S = safety and security. Role identifier M = Manager, Ma = 2nd Manager in same team, O = Operator, A = Trusted Adviser.

In the exit interview, Manager 2 in Team 2 was surprised by their high total score, which was likely to have resulted from the use of the Fibonacci scoring system, but also because this team member's answers even in the closed survey questions did not align with those of the rest of the team. The presentation of the data was considered useful both for internal and external use:

2Ma: 'I did not think it would look like that at all, I thought it would be probably around that 60—70% mark [referring to total score]. I think mine is a bit high and other people could do the same thing'.

2M: 'Depends how you would like to judge yourself; I don't think any of us are highfliers in industry terms, but as a group of farmers I think it reflects pretty well. It's a bit worrying that on Plan and Organise I am probably the lowest and I probably do most of the planning and organising … If we are looking at staff, something like this might be interesting to do when you have applicants for a job maybe, thinking more broadly these types of assessments would be quite good'.

2A: 'I think, having that spider map is helpful to manage the expectation on what level of the chain you are going to need to provide some of the support. It's easy to take [experience] for granted; just because they have had tech for a long time doesn't necessarily mean they use it'.

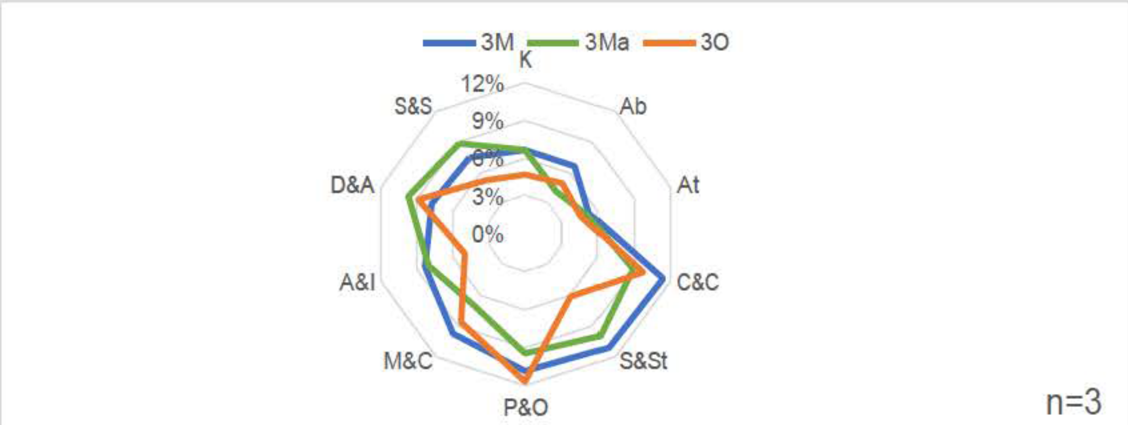


Figure 8.7

Percentage Contribution of Skill and Characteristic Scores to Total Maturity Score by Role—Team 3

Note. K = knowledge, Ab = ability, At = attitude, C&C = communicate and collaborate, S&St = select and setup, P&O = plan and organise, M&C = monitor and collate, A&I = analyse and interpret, D&A = decide and act, S&S = safety and security. Role identifier M = Manager, Ma = 2nd Manager in same team, O = Operator, A = Trusted Adviser.

In the exit interview Team 3 was asked if they considered the DKSA to be useful, which elicited the following responses:

3M: 'I actually thought this was one of the better ones'.

3Ma: 'pretty good, it was ok. Probably useful to find people's weaknesses, or what they are not confident in, to help them improve'.

3O: 'I felt lost in a couple of the questions. It's a bit of the digital language that can be tricky'.

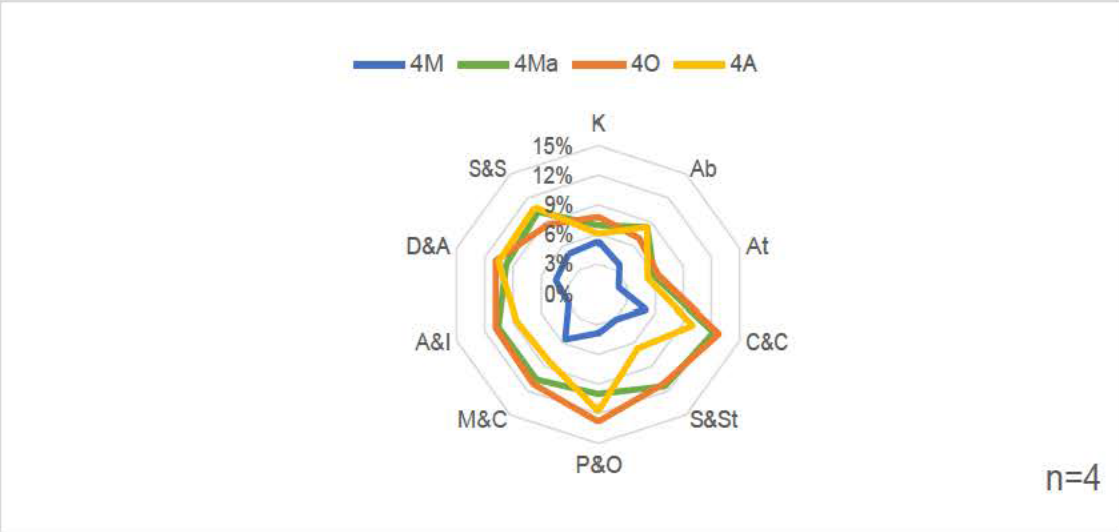


Figure 8.8

Percentage Contribution of Skill and Characteristic Scores to Total Maturity Score by Role—Team 4

Note. K = knowledge, Ab = ability, At = attitude, C&C = communicate and collaborate, S&St = select and setup, P&O = plan and organise, M&C = monitor and collate, A&I = analyse and interpret, D&A = decide and act, S&S = safety and security. Role identifier M = Manager, Ma = 2nd Manager in same team, O = Operator, A = Trusted Adviser.

The DKSA designed was found to be simple and intuitive for all except one participant, a Manager in Team 4. This was most likely because of the Manager failing to answer a question, which prevented completion. This problem highlighted that even the simplest evaluation tool could require support. In the exit interview, which was only with the two Managers in Team 4, considerable differences in interest in the use of digital were expressed as well as a lack of knowledge of their employees' enthusiasm for the use of digital solutions, which they considered valuable learning for all team members completing the DKSA:

> 4M: 'I don't have the patience and all my scores on that chart, they just went progressively lower as I got more annoyed because I had to keep doing the survey, until I could get it to work'.
>
> 4Ma: 'You set it out simply so we can quickly understand. And good to see what the others were thinking. [O] does appear more capable in some areas than we are, so we need to be putting him to work in that space. That is a conversation we need to have, so that is good to know'.
>
> 4Ma: 'If you are trying to work out what roles and responsibilities in your team might be able to take on, it's like doing that personality skills testing. You get an idea of where people's strengths and weaknesses lie. I think that is good from that point of view too'.

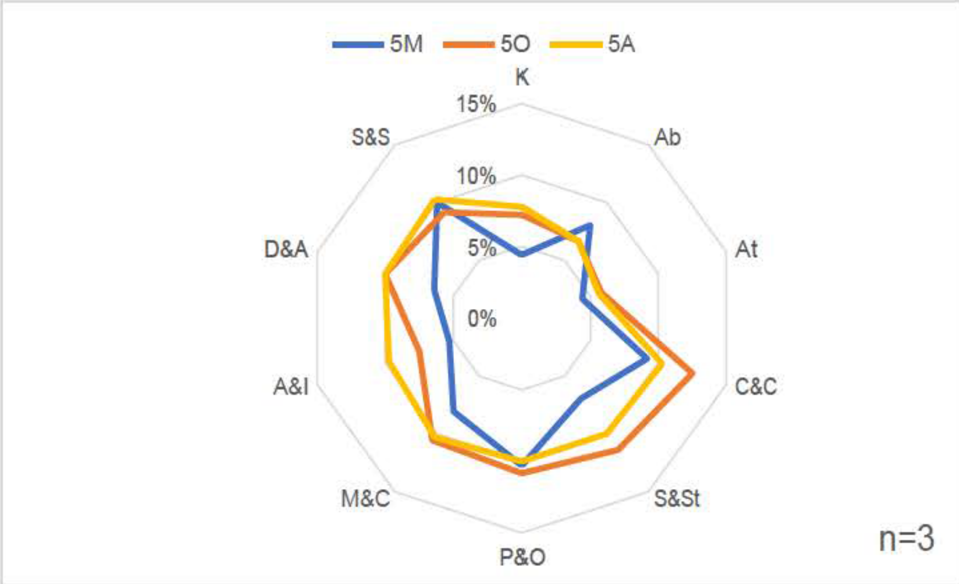


Figure 8.9

Percentage Contribution of Skill and Characteristic Scores to Total Maturity Score by Role—Team 5

Note. K = knowledge, Ab = ability, At = attitude, C&C = communicate and collaborate, S&St = select and setup, P&O = plan and organise, M&C = monitor and collate, A&I = analyse and interpret, D&A = decide and act, S&S = safety and security. Role identifier M = Manager, Ma = 2nd Manager in same team, O = Operator, A = Trusted Adviser.

Team 5 were asked how they felt about their DKSA scores during the exit interview and they provided the following responses:

5M: 'yes probably about right'.

5O: 'seems pretty fair. The way it's presented here, these results are not too hard to interpret. The surveys are easy to do. I don't mind long surveys like this, I find them pretty quick and easy to do. The results are pretty simple to look at'.

5A: 'fine. It is just a matter of trying to interpret correctly what it is telling you, I am thinking through'.

8.1.4 Summary Section 8.1

The structure the DKSA proved to be acceptable, with a reported mean completion time of around 10 minutes. The ability to deconstruct results by skills and characteristics provided an easy-to-interpret interface that was appreciated. The subjective assessment and use of validation questions meant the content of the tool and maturity stages were appropriate for measuring the digital skills and characteristics of personnel in a range of roles in a family farming business.

Scores could be provided for digital maturity as a total score, and by skills and characteristics—the latter offering insight into an individual's digital strengths and weakness. Accuracy of scores was discussed in the exit interviews. A few participants felt their ability was overestimated, while others gained confidence from achieving a higher score than they anticipated. The use of the weighted scoring system for several questions may have resulted in the overestimation of the total DKSA score for some participants.

Insight provided by the DKSA could be used to identify training needs or capitalise on skills not already being used by a business. Participant feedback in the exit interviews supported the value of the tool and its use to help quantify digital knowhow and support discussion around digital change.

8.2 Farming Businesses Digital Process Maturity Tool

The design of the DPM was similar to that of the DKSA, having components, core areas and subcomponents, and focus activities (Figure 8.10). Unlike the DKSA, which was designed to provide a capability score for skills and characteristics, the aim of the DPM was to establish the current and desired digital state; that is, to:

- identify current and desired use of digital technologies and data in relation to specific on-farm activities
- relate these states to a maturity index.

Each of the 22 focus activities was represented by four statements and each participant was requested to select the statement that they most closely associated with their current way of operating for that focus activity and the one that most closely represented their desired situation, resulting in 44 selections per participant. Only one statement for each option of ‘now’ and ‘desired’ should have been able to be selected per focus activity, but despite pre-circulation testing, it was discovered that the circulated survey instrument allowed multiple selections and prevented selections from being deleted. The survey was reformatted and retested, but the problem persisted and participants were not inclined to complete the tool a third time.

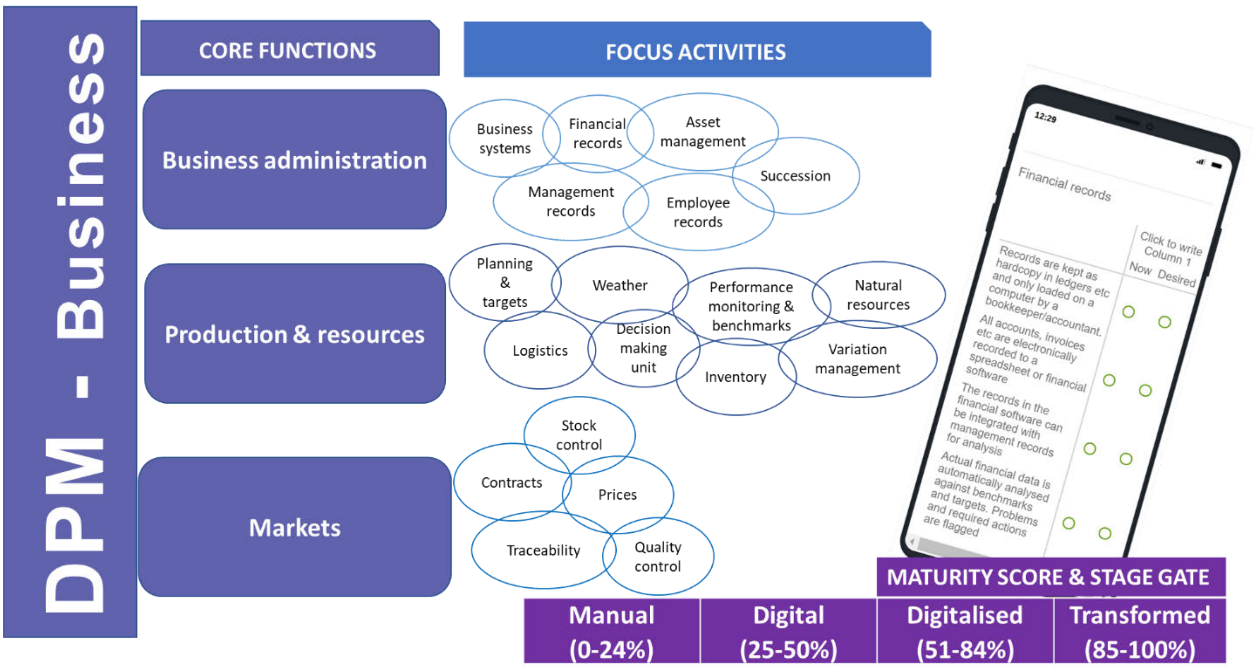


Figure 8.10

The Components of the DPM Tool and Scores

8.2.1 DPM Circulation and Response Time

The link to the DPM, which could be accessed as a mobile or web-based version, was circulated only to the eight Managers. They voluntarily shared it with other family members in their team, resulting in a total of 12 responses being received. All Managers from all teams responded and Teams 1, 3 and 5 returned responses from family members who were participating in other roles. These additional responses provided valuable insights within the team and indicated an enthusiasm for the use of the DPM and the results it could provide.

The mean completion time was 16 minutes with a range of 7–29 minutes as recorded by Qualtrics. Participants were not asked to report their completion time. Assuming completion was uninterrupted, as the timer continued while the survey remained open and unfinished, the average completion time indicated an average of 28 seconds was spent responding to each focus activity and validation question. During the exit interviews, no negative comments were received regarding the time required to complete the DPM.

8.2.2 DPM Analysis

All responses were downloaded to Excel for analysis. Each selection was recorded by Qualtrics as ‘now’ or ‘desired’ and converted to dichotomous scoring in Excel. Every selection received a score of ‘1; and a non-selection, ‘0. This gave a team with two respondents a maximum score of 88 and with three, 132.

From the 12 respondents, there should have been a total of 264 responses for ‘now’ and 264 for ‘desired’, giving a maximum score of 528. However, multiple answers to many statements resulted in a total of 534 based on 333 responses to ‘now’, (+26%) and 201 responses to ‘desired’, (−24%). When summed by response agreement or disagreement to the current and desired level, 98 statements were selected consistently by all respondents within a team, and 203 were inconsistent. There was no obvious pattern of consistent responses by focus activity, maturity stage, or the current or desired state (see Appendix K). For a focus activity to be digitised, stage gate three (digitised process) needed to be attained.

Responses were allocated to one of three categorise (Table 8.3), which are presented visually for Team 1in Figure 8.11:

- Consistent—all respondents from the same team selected the same statement
- Inconsistent— different stages were selected for the same statement by members of a team
- Contradictory—one member selected 'now' and another, 'desired', for the same statement.

Table 8.3

Responses to the DPM by Team and Category

Team no.	Maximum	Actual	*Consistent		*Inconsistent		**Contradictory	***Correct
Score			Responses by team					
	[1]n = 2 [2]n = 3		N	D	N	D		
1	[1]88	84	15	8	22	16	5	3
2	[1]88	136	25	14	24	34	15	1
3	[2]132	111	10	1	15	15	4	2
4	[1]88	74	13	0	22	26	6	0
5	[2]132	129	11	1	23	26	6	1
All	528	534	74	24	106	117	36	

Note: N = now, D = desired. *Totals are greater than 22 because of multiple answers per focus activity. **Included in inconsistent. ***Correct = answered as requested in instructions.

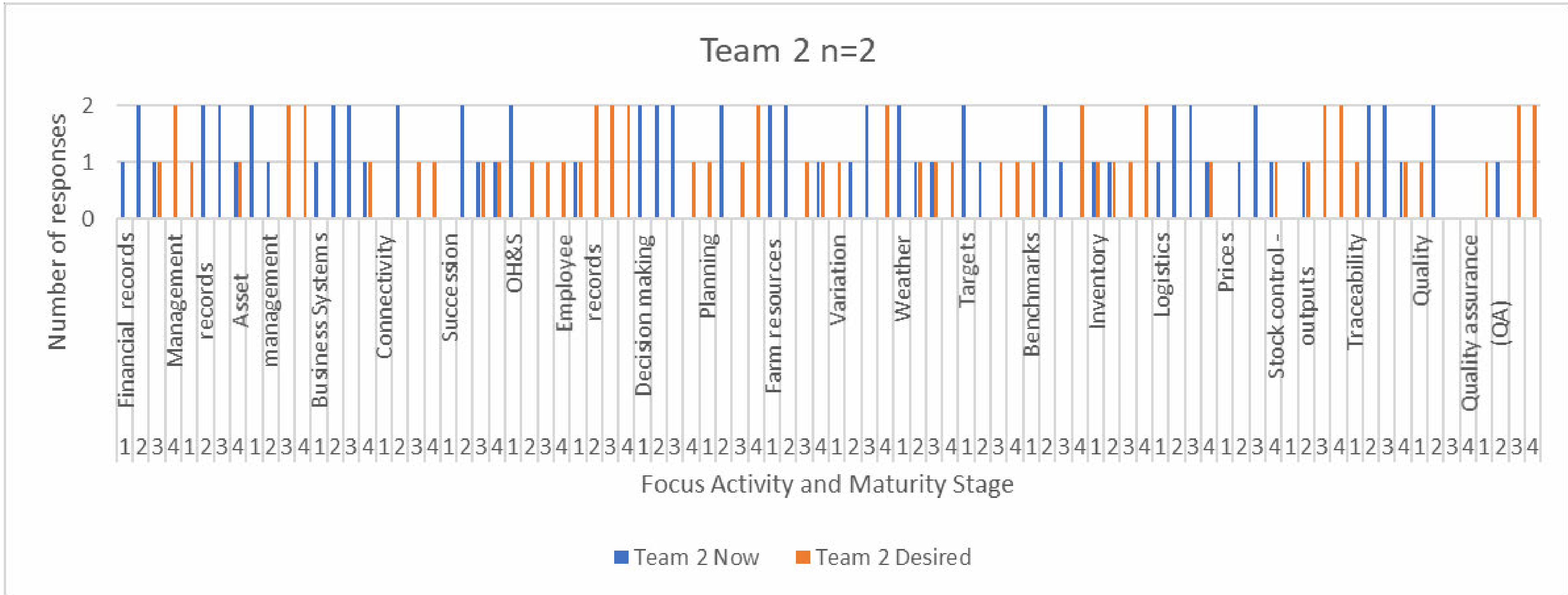


Figure 8.11

Team 2 Responses by Focus Activity of Current and Desired Maturity Level, Illustrating Consistency, Inconsistency and Contradiction

Note. Maturity level 1 = manual, 2 = digital, 3 = digitalised, 4 = digitally transformed.

Of the 22 focus activities, only six were responded to as requested by at least one of the five teams: business systems, connectivity, weather, inventory (by two teams), logistics and traceability (Table 8.3). The issue of inconsistent responses by team and focus activity was discussed with participants in the exit interviews. Multiple responses occurred either because the platform did not allow a wrong selection to be removed, or participants considered parts of two statements to be relevant, as indicated by feedback during the exit interviews suggesting the statements were not sufficiently discrete:

> Team 1: 'I struggled answering where we want to be as that is up to … [a returning family member]'.
>
> Team 2: 'Once I had the feel for how the questions were being asked, I thought it was pretty good'.
>
> Team 2: 'I could have answered that from a cropping enterprise, livestock enterprise and an overall business. I think we could have done it for individual enterprises to have drawn down a bit more'.
>
> Team 3: 'We are happy where we are. I had problems unchecking, it would not let me do it'.
>
> Team 3: 'You would read through [a statement], and it had a few too many options. I would agree with some of them but not all of them. That made it a little bit hard to answer some of them'.
>
> Team 4: 'I agreed with half the statement but completely disagreed with the second half, so if it were a shorter statement with just one think in it, I would have been able to do it'.
>
> Team 5: 'It was fine. There were a couple of questions, where I thought it was not quite the right question, none of the answers really worked for me. I am

not sure if I put an answer on every question. I got a bit confused, so probably, I did not do it properly'.

8.2.3 Content Validity of DPM

Content validity is often a subjective measurement based on the experience and knowledge of the participants and researcher. The situation statements used to populate the DPM were supported by the data collection instruments. Feedback from the exit interviews supported this subjective assessment of validity:

> Team 2: 'It's so easy to get focussed on what I am looking for [as a consultant] but it's really good to have that sort of levelling component [DPM] of where it sits in the priorities for a farm manager'.
>
> Team 4: 'It [DPM] definitely helped me work through our needs. I am not afraid of trying digital things, it's really just a time issue. I was not really sure where to start with some of this stuff, so seeing those questions that you have put together made me think "yes, that could be useful". It has given me a bit of insight into what is possible and also showed me that we are a long way from it, but it is something worth thinking about'.
>
> Team 5: 'If you see half the team desires something and the others don't, you have got to say why, great place to start the discussion. Just thinking of the size of what you have done here, the family would need to sit down and prioritise one section at a time'.

The objective of the validation questions was to identify if the focus activities identified as already digital were supported by digitised datasets and what would be required to meet the desired state. The structure of the validation presented did not meet this requirement, with questions being too general. Further development is required but the following describes the results from the process tested.

The 12 validation questions related to five datasets: financial, production and marketing, relating directly to the core business functions; environmental, which is aligned with production and resource management; and compliance, which is located in business management but has a direct influence from the other two functions, for example the provision of statutory declarations regarding a pesticide used on a crop when the crop is sold. Five questions asked about the importance placed on each dataset by ranking them on a 100-point scale, with 0 = not important and 100, extremely important. Five questions asked which of these datasets were already combined for analysis (results are not reported here because of a survey structural design problem). In addition, two questions asked participants to rank the importance they placed on calibrating equipment and validating data.

Responses to the validation questions highlighted and confirmed the inconsistency of priorities between team members, as seen in the DPM, in relation to the importance placed on different datasets (Figure 8.12). Production and financial data were considered the most important by the majority. When the rankings were presented as a mean for the population, the ranking was from most important to least important: financial>production>compliance>marketing>environmental.

Inconsistency was again reported by role and team in the importance placed on equipment calibration and validation of data(Figure 8.13). Operators all rated equipment calibration higher than validation of data.

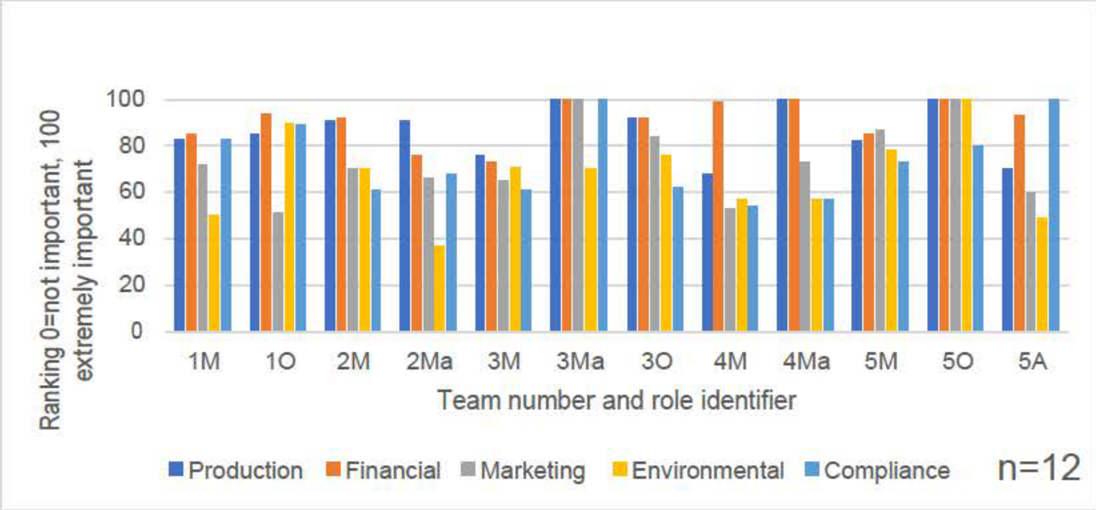


Figure 8.12

Ranking for Dataset Importance in the Validation Questions DPM

Note. Role identifier M = Manager, Ma = 2nd Manager in same team, O = Operator, A = Trusted Adviser.

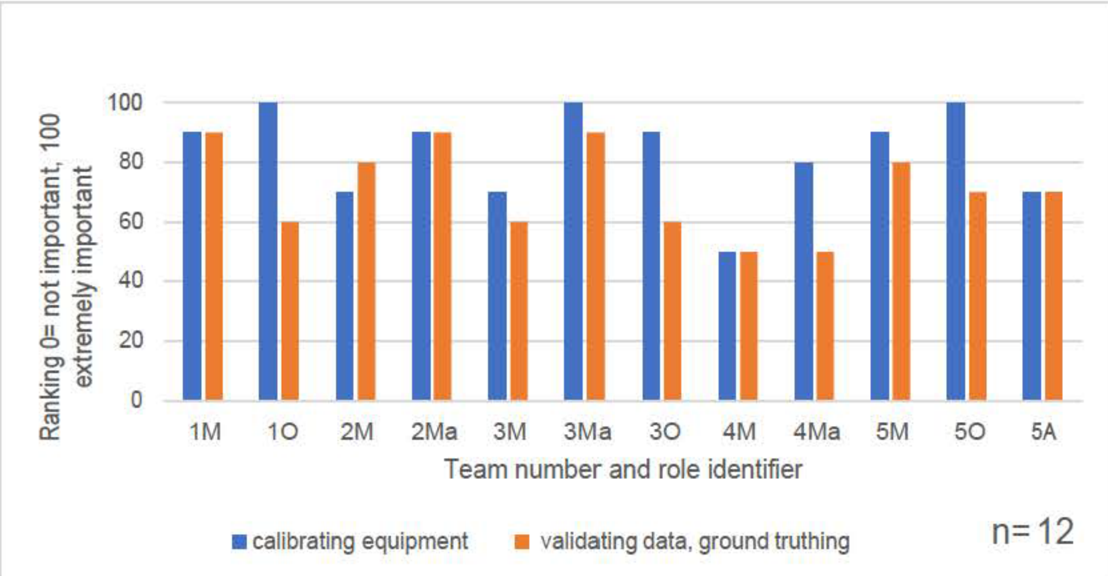


Figure 8.13

Ranking of Importance of Equipment Calibration and Data Validation

Note. Role identifier M = Manager, Ma = 2nd Manager in same team, O = Operator, A = Trusted Adviser.

A team's consistent responses in regard to focus activities at stage gate three were compared with the two most important datasets reported in the validation questions (Table 8.4) Focus Activities Selected by All Team Respondents at Stage Gate 3 Currently or in the Future, Aligned to Validation Responses and Responses to Video 2. No comparison could be made for Teams 3 and 4 as no focus activity was consistently selected at stage 3 or above. The alignment of statement selection and responses to validation questions for Teams 1, 2 and 5 suggested content validity for the DPM. However, the design of the validation would benefit from increased specificity regarding datasets to improve alignment with the focus activities rather than core functions. When compared with the interoperable datasets required for the proposed change following Video 2, the DPM identified differences between the datasets desired by the team and that required to be at stage gate 3, to achieve digitalisation of the system proposed by team members. The key areas of difference related to some of the proposed changes requiring digitised OH&S, compliance and regulatory data.

Table 8.4

Focus Activities Selected by All Team Respondents at Stage Gate 3 Currently or in the Future, Aligned to Validation Responses and Responses to Video 2

Team no.	Focus activity stage gate 3 or more		Most important data type	Priority datasets for change proposed in Video 2
	Now	Desired	From validation	
1	Management records Succession Logistics Stock control	Business systems Connectivity Planning Logistics Prices	Production Financial	Performance and quality monitoring OH&S & security
2	Management records Business systems Decision making	Asset management Employee records Planning	Production Financial	Management & tax records Performance & quality monitoring Input inventory & logistics

Team no.	Focus activity stage gate 3 or more		Most important data type	Priority datasets for change proposed in Video 2
	Now	Desired	From validation	
2	Variation Logistics Price Traceability	Benchmarking Inventory Logistics Stock control Quality assurance		Planning, organisation & maintenance
3	-	Variation	Production Financial Marketing	Performance & quality monitoring Input inventory & logistics OH&S & security Legal, regulatory & compliance
4	-	-	Financial Production	Planning, organisation & maintenance Performance and quality & Input & output inventories, logistics management & tax records
5	Benchmarking Logistics Prices	Business systems	All—each scored 100% important by one or more participant	Planning, organisation & maintenance, performance & quality monitoring

8.2.4 Maturity Scoring

Despite the problem with multiple selections by focus activity, a digital maturity score was applied to illustrate how the data from the tool could be converted to a maturity rating. The stage gate with the most ‘now’ selections was the maturity level achieved. As the number of focus activities in the next maturity level increased, those in the previous maturity level should decrease. The total number of sections should equal the sum of the maximum sections multiplied by the number of team members reporting; that is, 22 per team member reporting.

As all the teams made multiple selections for ‘now’ in the same focus activity, the total scores exceeded the 22 per person for the current state (Table 8.5). In this example, maturity was calculated using the total number of responses provided. For each team, the ‘now’ selections for each stage gate were summed, which identified that all teams had the greatest number of selections at stage gate 2, digitalised (Table 8.5). The same calculations were undertaken for the desired state and presented with the selection by stage for the ‘now’ state by team (Figure 8.14). While the data are limited because of the issue of multiple selections within a focus activity, they illustrate the type of information that can be conveyed using the DPM for a farming business regarding their current and desired state of digital process maturity.

Table 8.5

Total ‘Now’ Statements Selected by Stage Gate by Team

Stage gate	Team 1	Team 2	Team 3	Team 4	Team 5
1 Manual	7	17	15	18	24
2 Digitalised	26	32	42	26	39
3 Digitised	15	18	16	4	20
4 Digitally transformed	4	7	0	0	3
Total	52	74	73	48	86

Note. Teams 1, 2 & 4 n = 2, total score should be 44. Teams 3 & 5 n = 3, total score should be 66. Higher scores because of multiple selections.

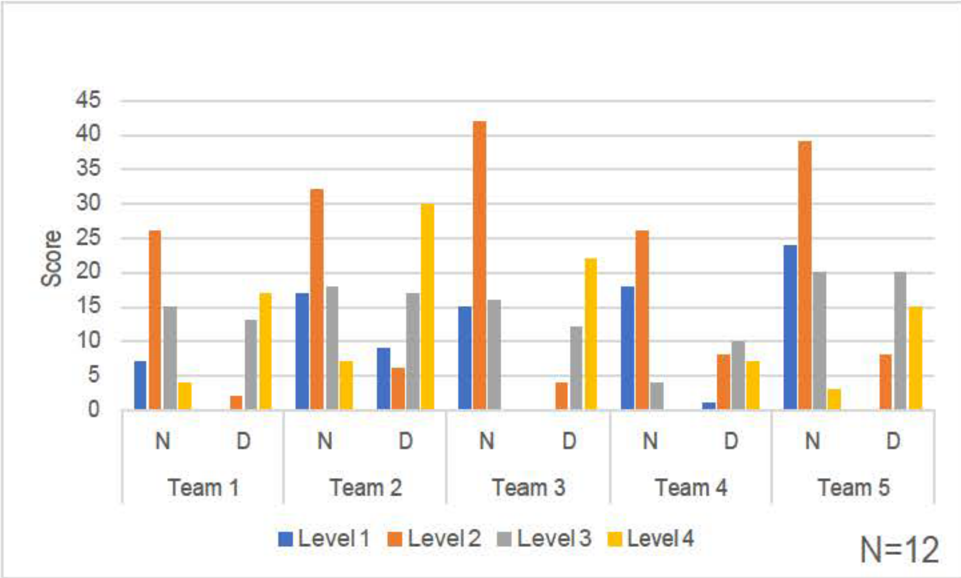


Figure 8.14

Responses by Maturity Level for 'Now' and 'Desired' State by Team

Note. N = now, D = desired. Maturity level 1 = manual, 2 = digital, 3 = digitalised, 4 = digitally transformed.

None of the teams had achieved full digitisation of all focus areas, indicating that 'manual systems' continued to be operated (Table 8.5). Depending on size and structure of the business, manual systems were likely to continue, as demonstrated by this quote from Team 4: 'M is really good at keeping everything in his head and he can run a really successful business just in his own mental inventory'.

8.2.5 Summary Section 8.2

The structure of the DPM proved to meet the criteria for a quick and easy tool to identify current and desired maturity in digital process, and to identify consistency and inconsistency among views within a team. Indeed, more team members supplied responses than were requested, as the tool was only sent to Managers.

The DPM testing was limited by problems with the survey platform and lack of discreteness of some statements. In addition, the structure of the validation questions did not allow responses to be easily aligned with focus activities. Despite these issues, the DPM received positive feedback from the participants and showed potential. Datasets required to achieve the change proposed in Video 2 were compared with the results from the DPM, which identified some differences between dataset priorities according to the DPM response and those required to achieve digitalisation of the process. These results indicated that the DPM had the potential to guide decisions about data interoperability requirements when evaluating a digital change.

Even with these limitations, the DPM clearly identified lack of consistency between team members in their perception of the current situation and desired state. The ability of the DPM to provide a structure for discussion about digital priorities and change was valued by the participants. The outputs from the DPM were considered by the teams to help stimulate discussion regarding the specific processes, datasets and technologies required to achieve a digital change, help identify inconsistencies in opinions, and develop consistency of understanding and objectives.

Even with the imperfect implementation of the DPM, the application of a process for converting the team responses into a maturity score appeared to be appropriate. Modifications to address the limitations and further pilot testing of the DPM is required before a wide-scale validation trial can be undertaken.

8.3 Summary Chapter 8

Prior to the start of this research none of the teams had used a strategic or structured approach to make decisions about the adoption of DA. They had no quantifiable method to convey digital capability or digitisation of process. All 17 remaining team members provided multiple rounds of feedback on the DKSA. All Managers, plus four additional family members, tested the DPM. Through the iterative process they provided constructive modifications and, in several cases, greater detail than requested. Working with multiple members of a single business proved a valuable way to test suitability with a range of roles and to identify consistency or inconsistency between individuals' responses. The level of engagement plus supporting comments gathered during the exit interviews indicated that both evaluation tools provided results of interest and relevance.

By using designs that prioritised completion speed over exactness, both tools met the objectives of being quick and easy to use, taking a mean completion time of ~10 minutes for the DKSA and ~16 minutes for the DPM. Completion using only tacit knowledge resulted in short completion times and helped keep participants engaged in the process. The production of a score was popular and stimulated discussion regarding roles, unused skills and training needs in the exit interviews.

The DPM offers the additional facility of identifying the desired process state, which is required to help direct change. Outputs from both tools can be used to support digital change using the adoption framework by highlighting strengths and weaknesses in the current state. The DPM can identify the desired state and identify whether the datasets required for the change are at the appropriate level of digital maturity.

This preparatory work has laid the foundation for future research to test these evaluation tools with a sufficiently large sample using factor analysis to measure the tools' internal consistency (reliability) and construct validity to ensure they reflect the intended components and subcomponents.

Chapter 9: Discussion

In this chapter, the research findings regarding the DA adoption journey of family farming businesses are discussed against a backdrop of the published literature. Particular attention is paid to the factors found to shape the individual's perception of DA value and the part an adoption framework can play to guide this journey. This discussion responds to the main research question and sub-questions addressed by this mixed methods research which is dominated by qualitative results:

RQM*: How can an adoption framework improve uptake and use of digital agriculture by a family farming business?*

RQ1*: What are the fundamental components of digital agriculture for grain, livestock and mixed farming businesses?*

RQ2*: Why and how do farm businesses initiate the use of digital technologies for farm management and how could this be supported by a change management approach?*

RQ3*: How do commercial providers of digital agricultural hardware, software or support services, view and address the barriers to uptake of digital agriculture?*

Two new resources were developed from the research findings: the DA adoption ecosystem checklist; and the fully populated DA adoption framework. The ecosystem checklist is a reference tool for developers and providers to support development and implantation of digital solutions that are appropriate to family farming businesses. Through the course of the research the DA adoption framework, which is designed to help family farming businesses navigate their DA adoption journey was evolved from the conceptual version presented in the methodology. These resources help both developers and providers address DA adoption from a people and process perspective, rather than the current task and technology approach.

9.1 The Adoption Journey

Adoption of DA was referred to as a ‘journey’ by providers and team members. Consider a road trip: it has a starting point, a mode of transport, a destination, and some assumed or sourced knowledge regarding how to reach the destination (a map). However, initiation of the journey requires more than physical elements; the traveller needs to be aware of the reason for the journey, and to have the motivation and time to make the journey. The success, enjoyment, cost and duration of the journey depends on all elements being addressed to a greater or lesser degree. This is true too for adoption, especially of a complex change such as DA, and this journey is often very specific to the individual farming business (Montes de Oca Munguia et al., 2021). As with a journey, knowing your current position in terms of digital capability and process makes adoption more direct and practical. Thus, the development of the evaluation tools became a focus of this research.

The overarching aim of this research was to use academic approaches to work with family farming businesses to produce practical solutions to guide their DA adoption journey. Along the route, the participation of providers presented the opportunity to gather an alternative perspective on the elements and influencers of the adoption journey. This addition enhanced the breadth and depth of the research and resulted in the development of an additional adoption framework specifically for use by developers and providers of DA.

The premise of this research was that the family farming business lacks a planned approach to digital adoption. The opportunity and ever increasing application of digital innovation is assumed (Rojo-Gimeno et al., 2019; Shepherd et al., 2020) and the research is founded on the fact that farming businesses are struggling to adopt DA primarily because of six barriers identified in previous research (Leonard et al., 2017):

- lack of a legal framework around data and trust regarding third-party data use
- the need for universal, reliable telecommunications connectivity
- lack of clear value propositions for users
- low levels of digital literacy across the value chain
- availability of appropriate data
- a need for platforms for data analytics and DSTs.

Data collected from members of the teams and providers indicated these barriers continued to exist. A concerning finding was that both parties reported an ongoing struggle to identify and convey clear value propositions for adopting DA and issue raised by others including Rojo-Gimeno et al. (2019) in their value of information model. The fact that identification of value remained elusive to both providers and users was taken as a clear disconnect between those driving and delivering DA policy, research and development and the potential needs and wants of the end users (Fleming et al., 2021; Ingram et al., 2022; Lajoie-O'Malley et al., 2020).

An important finding from this research is that the barriers cannot be considered as six separate factors. Participant responses reported in Chapters 5 and 6 identified not only that these barriers persist, but that they are interdependent. All six barriers influence an individual's perception of the value proposition of a DA solution to a greater or lesser extent (Figure 9.1). For example, simply solving telecommunication connectivity issues or providing data collection and storage tools without analytical ability is not enough: these are incomplete solutions. Even having the 'perfect technology' is never enough if the value perspective of the user is not considered. Those designing and delivering digital solutions need to consider all barriers together, not in isolation. Understanding the relationship between these technological and human factors in relation to digital change is at the core of these research findings. This is a theme that weaves its way through all sections of this discussion.

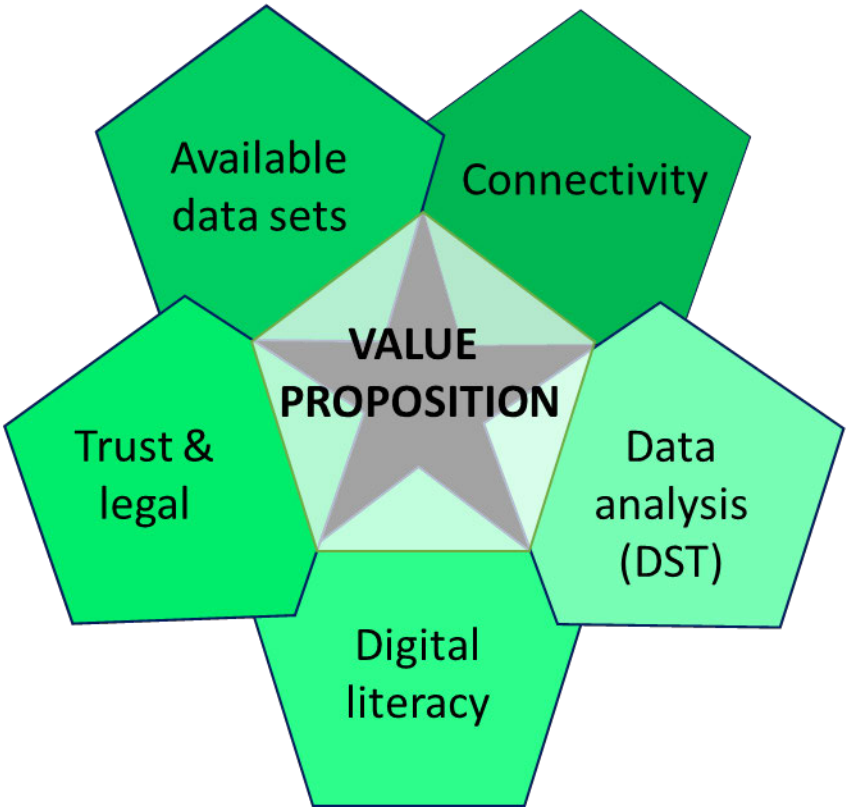


Figure 9.1

The Six Barriers to Adoption of DA are Interrelated

Note. Those designing and delivering digital solutions need to consider all barriers together, not in isolation.

The inherent complexity of DA adoption is based on the interdependency of these barriers, which influence both technology and human factors. In other industry sectors this digital complexity is supported by structured approaches to change (Deloitte, n.d.; Savic, 2019). The farming sector is no stranger to such systems thinking and process application. Structured approaches have been developed and implemented for agriculture production processes: two such examples are weed control (Wilson et al., 2009) and sheep performance management (AskBill, 2018). However, the application of structured approaches used in other industry sectors is not commonly reported by family farming businesses, the target population for this research. Indeed, the change management approach proposed as part of this research was unfamiliar to the members of the teams; yet it was received positively as noted by the additional responses received during the assessment phases and when discussed in the exit interviews. As one participant noted, ‘without a framework and communication, you don’t realise which direction you’re going and that you’re here, you’re here and you’re here [pointing to other team members] and it’s hard to salvage and get the whole farm working properly’.

A central pillar of successful change management is ensuring all team members are working towards a common goal. This requires good communication. Family businesses are recognised to suffer from relying on tacit knowledge and poor internal communication, and farming businesses are no different (Hubler, 2009; Pitts et al., 2009; Poza et al., 1998). They are also recognised to align management and operation decisions with the personal goals of the owners. Indeed, Fulton and Vanclay (2011) categorically stated that change is more likely to occur when the advantages of the technology align with the personal goals of those in the farming business. These factors were primary considerations in the development of this research and the adoption framework. The issues of lack of communication and lack of tactical approaches to change were both clearly observed and are discussed in Sections 9.2.2 and 9.3.

Poor internal communication is widely recognised as a limitation of family business structures (Poza et al., 1998). Rather than working with a single representative from a business, this research involved multiple members of a business serving different roles—including an external trusted adviser. The use of this inclusive approach was welcomed by the teams, as expressed by Team 1, although it created additional difficulty when enrolling participants at the start of the research: ‘I thought that was really good that the three of us could put our ideas forward, it just makes you aware of that’s what they’re thinking and what to prioritise’. Without the use of the team approach to data collection, these issues of differences in goals between team members and the need for approaches to improve communication is unlikely to have been observed.

Developers, providers and potential users of DA need to perceive the value proposition of change if digital is to be integrated into the farming system. By providing quantified results the evaluation tools in this research helped to stimulate dialogue around individuals’ scores and perceptions of the facts. Improving a family farming business’ ability to articulate their specific DA value proposition can help developers and providers better understand market requirements. It is envisaged that with this shared knowledge more appropriate digital goods and services can be developed and identified for adoption by a family farming business. However, until a more planned approach is implemented, the motivation to start the DA adoption journey will be lacking, the starting point will remain unclear and the digital offerings will be mismatched with users’ desires. The use of such evaluation and planning tools is likely to require support through extension or trusted advisors (Ayre et al., 2019; Rijswijk et al., 2019).

9.1.1 Current Perception and Use of Digital Agriculture

Despite the plethora of digital technologies being developed or commercialised for the agriculture and food industries (AgFunder, 2020), the range of technologies adopted by the teams in this study was found to be extremely narrow and generally not unique to agriculture. Less than 50% of the 20 technologies used for management, communication, guidance, imaging, sensing or measuring were used by one or more of the 18 participants. This clearly illustrates a degree of disillusionment regarding the digital options currently available. Issues of ease of use, reliability, longevity in the market, data use, after-sales support and value were all raised as factors that reduced the perceived value of DA and increased caution regarding changing from an incumbent solution. These technological and socio-ethical barriers have been continued to be identified in studies across the globe (Shepherd et al., 2020).

All participants in the family teams used a mobile phone for voice and text messages; all had access to a laptop or desktop computer or to a touch screen device such as a tablet; and the majority had access to the internet. This finding is mirrored by Marshall et al. (2020) on rural digital inclusion The majority also used GPS guidance and autosteer. The main uses of digital technology were reported to be communication and sharing information, followed by collection and storing of data. Mobile phone connectivity in the office and across the farm were considered important, and internet connectivity extremely important especially for management of finances (e-accounting, e-banking) and sourcing information. Nonetheless, lack of ubiquitous connectivity across the farm was not considered an insurmountable barrier in the adoption of digital solutions but connectivity remains a fundamental issue despite this Barrett and Rose (2022) in their review technologies for Agriculture 4.0 failed to acknowledge the importance of connectivity.

Similarly, the use of available software and farming apps was generally limited and those used were not always agriculture specific. Of the 21 agriculture-specific software products, an average of four was used by a single team. Farm management and financial software, and weather and marketing apps were the most widely used. The Agworld[2] software and app, and the Willy Weather[3] mobile app had multiple users across teams, but even these were not used universally. The Agworld software is particularly focussed around input recommendations from agronomists who pay a subscription for use but who can then share outputs with clients via a free subscription. Willy Weather is a free Australian weather app, favoured by farmers for its visualisation of long-term weather, but not specifically designed for agriculture. These results indicate technology fragmentation, many technologies offering similar functions causing confusion in the market place and the importance placed on trusted advisers in the adoption of new technology.

Software used for farm management records and precision farming was the only agriculture-specific software reported. Having software and technology is one thing; using it for more than data collection and storage is another. The use of digital technology for analysis and creating actions from data was only reported by half of the Farm Business Team participants.

The limited number of software products used also related to lack of time to select and learn about new products. There was a general feeling from Managers and, to a degree, Trusted Advisers, that the products they needed were not available, easily identified or demonstrating value. As this quote from Team 5 reiterates, they wanted help: ‘We can spend a lot of time trying to find something that works. We just about need a pathway, a proven pathway to an outcome, that’s reasonably simple’.

[2] https://www.agworld.com/us/
[3] https://www.willyweather.com.au/

This need for guidance, a *proven pathway*, was reiterated in the surveys, and commercial interviews. Users considered technical and operational support to be lacking both in availability and ability. Some appeared resigned to the lack of support; others, such as Team 3, indicated frustration: ‘the worst thing is you spend $30K on a guidance system and a week later you know more than they do, than the salesman’.

Users spoke of a preference for less software or even a single universal product: ‘you have two different programs going on, and they both cost you subscriptions every year and that is what you have to work out, there is not always one program that suits everything we need’. Concern was raised regarding being locked into a product and the potential for data loss: ‘what happens is the big companies end up controlling your datasets and eventually you get locked in, which really worries me’. As the following quotes illustrate, lack of trust appeared to be greater in relation to data tenure than to data privacy; most were happy to share data with their Trusted Advisers such as agronomists and accountants:

> where our data is stored and what might happen to it down the track. Once you are locked into something, they can charge as much as they can get out of you; what they think they can get.
>
> then you don’t have access to the data that was on the previous program; as soon as you stop paying, you don’t have access to it.

These statements illustrate the negative experiences or perceptions of team members of DA technology and the potential influence on further adoption.

Critical analysis of the advantages versus the disadvantages of DA and of DA in comparison to other solutions is noticeably absent in the literature.

Understanding users and potential experiences and attitudes is important for providers and to the team to ensure they are addressed in future digital adoption activities.

Social proof, with recommendations from known users as well as supported hands-on trials, was considered central to successful adoption activities by both users and providers in this study. This need concurs with Rogers (2003) Diffusion of Innovation Theory and the need for awareness and the ability to observe and trial items to understand the perceived attributes of a technology. The importance of networks of practice was reported in relation to the adoption of PA by Eastwood et al. (2012)

Participants reported in the survey that adoption occurred when a technology met a need; that is, when they perceived it to meet their need, which in turn suggests the barriers to adoption have been sufficiently addressed to meet their personal goals or they are willing to provide the commitment to make a technology meet their need. Another influence on digital adoption was making the business appealing to the next generation, but not future employees. Indeed, team members were generally keen to adopt digitalisation, and viewed it as improving profitability, productivity and efficiency through greater collection and use of data. However, the technologies they were adopting tended to support a task rather than enable the digitalisation of a whole process—an issue that is discussed further in Section 9.2.2. The responses to the closed survey questions indicated that, in addition to digital technology being adopted when it met a need, a selected technology needed to be easy to use and provide a cost benefit; yet, the embodied-knowledge technologies adopted—specifically mobile phones and autosteer—primarily offered utility, which may or may not provide a financial return.

Perhaps this dichotomy indicates the potential limitations of closed survey questions, but of greater relevance to this research is that the indirect value provided by the adopted technologies had become implicit. This use of digital technologies for utility rather than financial gain was only indirectly acknowledged by the participants but is an important factor to consider when investigating perceptions of digital technology. In addition, the adopted technologies primarily supported the execution of a task, sharing information/communication or steering, they did not support data flowing up and down the value chain to improve efficiency, transparency and profitability. From participants' responses it could be deduced that usefulness was a more highly valued attribute than production of financial return, providing use of the technology was not anticipated to cause a loss. This on-farm perception and use of DA diverges from the potential and expectations presented in policy and research (Fleming et al., 2021; Montes de Oca Munguia et al., 2021) and reinforces the ad hoc, immature status of digital adoption as highlighted by Skinner et al. (2017).

Poza et al. (1998, p. 311) stated that 'often in business it is only what gets measured that gets done'. Participants illustrated that they valued the collection and use of data, but manual data continued to dominate over digital data. This suggests a data culture exists, but use of sophisticated and automated data analysis is lacking. While participants' digitalised data sources remain dominated by financial and production software, those would be the focus for improvement at the potential expense of factors indirectly related to production and profit. Thus, with digital adoption there is an element of egg and chicken: until new datasets are gathered, combined and analysed, the value of the outputs can be difficult to predict, yet without the digital technology these digitised data will not be available.

Team members' responses indicated them to be innovative or early adopters of digital technology based on the categorisation used by Rogers (2003, p. 281) (Figure 2.5). Such early adopters are prepared to put time and effort into refining a technology to better meet specific needs. However, participants indicated a preference for digital technology that was quick and easy to set up and learn, and made a job easier or more cost effective. They also reported some frustration with the lack of connectivity (a key enabling technology for digital) and poor experience with data interoperability; long-term data access; the complexity of selecting solutions; products failing quickly; and availability of credible support. One Commercial Provider referred to 'Excel hell' being the state before the current situation of 'app hell', and many users felt that fit-for-purpose digital solutions were lacking. The need for support was a recurring theme identified by users and providers. Both parties acknowledged that pre-sales guidance, after-sales backup and ongoing specialist support all had a role in successful, ongoing adoptions; paying for such services was less popular and is a potential weakness in DA adoption.

Differentiating the value placed on *manually collected data* versus *digitised data* was difficult. Operators were asked about their preference for how information was received and reported. In both of these, verbally, face to face was the delivery mechanism of choice, indicating a preference for analogue and anecdotal formats. Managers reported the use of data for simple and complex decisions. However, it appears that data tended to be siloed in manual systems or within proprietary products with limited interoperability options. Where interoperability existed, some users reported poor experiences because of inconsistent timing of software updates, for example. A few reported using Excel to bring together and analyse disparate datasets. The majority of participants considered equipment calibration at least as important as data validation, yet when installing field trials they often lacked baseline data or control treatment, reinforcing the observation that a culture of data analysis, rather than data collection is lacking. Such value sets may be so entrenched that an individual does not recognise it as a limitation unless specifically investigated (Rojo-Gimeno et al., 2019; Shepherd et al., 2020). A clearer picture of the types, quality and uses of data that are valued was revealed by responses to Videos 2 and 4 (Chapter 7).

The responses to the closed survey questions suggested the farming businesses did not differentiate between technology that improved farming operations and the use of data to improve decisions and actions—an observation that was overruled by the responses to the open questions in the video tutorials where sophisticated, agriculture-specific, interoperable digital solutions were described. The survey results concurred with the literature indicating that investment in digital technology is ad hoc and rather unplanned (Skinner et al., 2017). The inconsistency between team members' priorities for digitisation as expressed in their responses to the questions posed in the video tutorials reinforces the observation that digital adoption is not currently a planned process.

9.1.2 Unlocking the Value of Digital Agriculture

Exploring the initial steps of the Change Guide via the video tutorials created real examples of digitisation. Digitisation refers to conversion from manual to digital datasets; these in turn support the digitalisation of processes that use connected technologies—collecting, collating, integrating, analysing and acting on the digitised data (Savic, 2019). Three findings that are considered pivotal to unlocking the value of DA, which are reported in Sections 9.1.2.1 to 9.1.2.3 were revealed by the responses to the open questions. In turn, these responses elaborated on the information previously gathered by the surveys.

The video tutorials provided a novel and very successful data collection instrument. The depth of answers to the open questions was often greater than anticipated and several team members even initiated telephone conversations to explain and expand their responses. Participants considered the video tutorials the next best option to a face-to-face interview but with the additional advantage that they could re-watch the video and consider their answer in their own time. The combination of providing information in the video, followed by a concise question, helped illustrate the detail of response required from the participants. The responses indicated that these farming businesses had clear visions for a digital future, which often exceeded the technologies and services currently available. Th three pivotal

9.1.2.1 Sophisticated Workflows

In response to the question, 'What process on your farm would you like to be the first to be fully digitised', among the 17 remaining team members 12 distinctly different process were prioritised for digitisation. Members were asked to assume there were no constraints. Only one team could achieve their priorities with technology that was already used by the business. All processes required the integration of multiple datasets. Several teams had some of the required datasets and technology capable of contributing to the process but data interoperability was generally lacking. Digital components of some processes were yet to be developed, not available on the Australian market or regulated, preventing use in the participants' region.

A detailed response from a member of Team 3 to the question following Video 2 illustrates the sophistication of the process: 'I would like to see the chemical handling, storage and stock area fully digitised'. They went on to describe the steps for how they envisaged the digitisation of the spray process. These steps, enumerated below, are automatic unless a human role is noted. The part of step 6 in bold was already occurring on this farm. Similarly, the prescription in step 2 was already provided in a digitalised format.

Therefore, the majority of tasks in this process remained manual, despite being repeated five to eight times a year across every paddock of the 3,750 ha farmed by this business:

1. The operators attach a single fill line to the spray tank.
2. On a computer the paddock for the application is selected and ***the prescription*** of pesticides, nutrients, additives and water that has been uploaded by the agronomist is displayed and checked.
3. The operator selects '*fill*'; each product and the water are automatically measured, added in the correct order and mixed as required.
4. Products are deducted from the inventory, which is required for management and tax accounts.
5. The prescription and cost are allocated to the paddock in the farm management software.
6. The ***rate controller in the sprayer records the actual coverage map***, which is uploaded to the farm management software with the date and time.
7. Weather conditions at the start and end of the application are uploaded from the on-farm weather station to the farm management software.
8. The prescription, weather conditions, coverage map, and locations, date and time of operation are all automatically uploaded to compliance software.

This example integrates data from two of the three core function areas: production and resource management (planning, inventory, variation management, weather) and business administration (management records, compliance) (Figure 7.4). This process would require approximately five software packages to be interoperable, including the requirement for the agronomist to be able to provide a prescription compatible with the automatic fill and mix system. Logistics data (collection and transport of stock) and employee records (up to date certification) could also be required but interoperability is not considered essential to those datasets in this process. However, connectivity at the loading location would be required and this might be remote from the homestead. On investigation, it was found that many of these components were commercially available (not necessarily in Australia) but had not been integrated as a complete process workflow. This disconnect between the sophisticated digital process presented by the participant and the lack of a process approach by developers and by the policy makers and funders supporting development task based digital solutions is resulting in fragmented solutions, and products and data remaining siloed and preventing the evolution of digital to digitalised.

To enable these sophisticated workflows, a clear understanding of the current digital processes across the business is required to identify where else the datasets used in this process may also be required or already exist. These sophisticated workflows reinforced the interrelationship between all six barriers and why users have concerns over data tenure, because the loss of access to one dataset could jeopardise the whole workflow. Comments from providers suggested that users needed to be convinced about the value of DA but this study supports the argument that value is greater than financial return (Montes de Oca Munguia et al., 2021; Rojo-Gimeno et al., 2019). The sophistication of the processes presented by the teams suggests that providers should consider DA from a process perspective if value is to be captured by all parts of the value chain.

9.1.2.2 Lack of a Plan

In the survey, a lack of digital investment strategy was confirmed by all Managers. However, the aligned question about budget allocation for digital technology returned inconsistent responses between Managers in the same team. Different responses were also recorded from team members regarding functional factors such as number of sheep, area of productive and non-productive land, and how many blocks were farmed. Such discrepancies could be explained by different interpretations of questions, and emphasise the value of the team approach and the importance of unambiguous questions and flow-up fact checking. Such differences in responses may also indicate a disregard for data accuracy, placing a low value on data use; poor internal communication, or issues of data interpretation; comprehension or dyslexia; or a combination of the above. All of these factors limit a business's use of data and the perceived value of digitised data (Wolfert et al., 2017). These inconsistencies indicated that responses were coming from the head or the heart rather than from a recorded document.

This lack of consistency in responses was seen again in the choice of process proposed for digitisation, following Video 2. Priorities for digitisation were inconsistent between team members, even when proposals from external Trusted Advisers were excluded. However, two team members often had similar or interrelated priorities and these frequently aligned with the areas of responsibility or interest of the individual. The choices demonstrated a personal rather than strategic approach to managing change and capital investment. Despite results indicating the need to bring individuals to a common purpose, the teams reported that the lack of a plan to make change was not preventing them from making the change. The strongest factors preventing change were lack of knowledge, confidence and time. The irony is that investing time in planning is likely to save time and reap other rewards (Poza et al., 1998). Such conflicting tensions are common in family farming businesses but not necessarily recognised by the individuals until they are illuminated by a third party (Pitts et al., 2009).

Such inconsistencies in responses were only identified through the collection of data from multiple members of the team. This result emphasises the importance of the team approach to data collection from a family farming business. It also reinforces the need for clear communication and mechanisms for sharing ideas, experiences and needs, even within a small team. A clear understanding of why a change is required, and the benefits the change offers an individual in the team are the awareness and desire steps of the ADKAR change management framework (Hiatt, 2006). The inconsistency in responses indicates the team members were responding from a personal need perspective rather than one aligned to a business digitisation strategy. Responding from a personal perspective can fulfil the ‘A’ and ‘D’ steps of ADKAR for the individual but does not necessarily align with priorities of the business decision makers. The evaluation tools facilitated identification of the current strengths and weaknesses of digital capability and processes to aid discussion and planning of digital change priorities using the Change Guide.

9.1.2.3 Confusion Regarding Change Leadership

Successful adoption needs everyone to be working towards the same goal, so understanding the goal is crucial. The role of ‘change captain’ (introduced in Section 7.2, Video 3) is responsible for ensuring the whole team is informed, engaged and supported to implement and retain the process change to meet the goal. The change captain selected following Video 3 was always an internal family member. However, their feedback statements indicated some confusion about who should be selected and the roles of others.

Generally, Manager 1 was selected by all members, irrespective of their digital ability. The Trusted Advisers in Teams 1 and 5 nominated themselves; both were family members running independent businesses, but they were not nominated by the other team members. Thus, none of the teams nominated an external change leader, despite Managers reporting lack of time as a reason for not changing. Most teams ranked all internal members as important at a minimum in a hands-on or support role. How team members would be engaged, and their role communicated, was not explored.

How much can be inferred from these responses is questionable, partly because the change was hypothetical, and each team member responded in relation to their change priority. What was clear was that the concept of change management was not familiar to the teams. Despite this unfamiliarity, the use of a change process was viewed positively. However, it was considered that on-farm support would be required for a change management approach to gain traction with family farming businesses.

9.1.2.4 Driving Change

Lack of a clear value proposition for DA was reported in the top three adoption barriers by 79% of providers in this research. Despite their belief and commitment to delivering digital products and services, the providers appeared to be struggling with how this delivery was best achieved. Indeed, very few approaches to improve or support adoption were identified in this research and those presented reinforced a top down ‘show and tell’ approach with little engagement with trusted advisers (Ayre et al., 2019). This section of the discussion summarises these adoption barriers as experienced by providers of digital solutions and presents the DA adoption ecosystem checklist as a guide to help developers and providers address these barriers.

Achieving change from an incumbent to a new solution was an issue frequently addressed by the providers of digital hardware, software, services or combinations of these. It was acknowledged that handwritten and verbal data collection were the greatest challenge to the use of software-based systems.

For a digital option to be considered, providers indicated it needed to offer ‘10 times the value’ of the incumbent solution. providers often expressed frustration with the users for not seeing the value of going digital or accepting the associated costs. ‘it’s that mindset change thing; … it’s a different way of thinking going forward, its actually about embracing the technology’.

Many providers tried to support this mindset change by using case studies and providing free trials, help desks and training videos. Despite this, 75% of Managers reported a lack of support as a substantial impediment to digital adoption and 87% were cautious because digital made them more reliant on external parties, a fact also noted by Shepherd et al. (2020). The providers acknowledged that the networks surrounding the farming business were a huge influence, which could be positive or negative to adoption, depending on the individual's attitude to DA. While these influencers were acknowledged, few of the providers had engaged with them to progress on-farm adoption of digital solutions a finding reinforced by adoption research in New Zealand (Rijswijk et al., 2019). Those that provided services recognised themselves as influencers but admitted they themselves were struggling with the diversity of products and similar adoption barriers expressed by the teams. However, 66% of Trusted Advisers, compared with 50% of Managers, said they would use more digital technology if more training was available. Targeting digital products and training to agronomists has been a successful formula adopted by Agworld, the most widely used DA software.

The analysis of the commercial interviews (Chapter 6) recognised that the original six barriers (Leonard et al., 2017) persisted, and four additional barriers were identified: time, individuality, influencers and ecosystems. These additional barriers were reflected in the survey responses and exit interviews with the teams. The effect of time, influencers and individuality on adoption have been recognised in previous technology adoption and systems change research in agriculture (Fulton & Vanclay, 2011; Llewellyn, 2014; Pannell et al., 2011). In turn, the concept of DA as an ecosystem was acknowledged by Barry et al. (2017, p. 48), who described DA as an 'information ecosystem' using technology to gather, interpret, act on and share data along the whole value chain. However, Barry et al. (2017), Kruize et al. (2016) and others who have presented DA as an ecosystem tended to fall into the ‘technology trap’. To consider DA purely from the perspective of the technology and workflows completely fails to acknowledge the human influences on adoption (Kane, 2019).

Lack of skills, confidence, time and support from local dealers, as well as stage in career, were all human factors affecting adoption that were reported by the teams in this research. Left unconsidered, each of these could negatively influence successful adoption. Past experiences and belief system have a strong sway over an individual’s successful adoption of a new technology, and the importance of the human influence on adoption is widely reflected in the literature (Adams et al., 2017; Kerrigan, 2013; Pannell & Vanclay, 2011; Rogers, 2003). The novel use of a team approach in this research further highlighted the human influences through the inconsistency of participant answers, even within the same team. Understanding aspirational influences on management decisions in a family business is fundamental to digital offerings being embraced as a solution, or rejected (Kaine et al., 2011).

Consequently, this research proposes that ongoing adoption will only occur when digital products and services can show they meet the goals of potential users. For this to be achieved, the focus of information delivery regarding products and services needs to pay greater attention to human influences on adoption. However, this must not be at the expense of clear information regarding the task executed by the technology and its relationship to a process it supports; the interoperability of data; and the enabling technologies required. These recommendations concur with observations by Shepherd et al. (2020) who proposes that the main barriers to adoption will be socio-ethical and technology acceptance requires a clear demonstration of data being converted to ‘actionable knowledge’.

The DA adoption ecosystem checklist (Figure 9.2) was designed to highlight the key human and technology factors that need to be considered when demonstrating the value proposition of a digital product or service. This is deliberately called a checklist and not a model as it does not meet the three functions of an adoption model presented by Oscar Montes de Oca et al. (2021). The checklist is presented as a hierarchy of needs constructed around the themes and subthemes extracted from the data analysis (Figure 6.5). The technology and data factors are process, data use, connectivity, data availability and hardware. The people factors are value proposition, influences, individuality, digital literacy, trust and legal, and time. Products and services need to consider the items at the top of the hierarchy and work down; all factors must be considered but will have different effects on adoption depending on the product or service being delivered and the target market. By using the ecosystem as a planning tool with potential users of digital products and services, developers and providers will be better able to clarify value propositions. Where appropriate, items from the DA adoption ecosystem checklist are mirrored in the three-part adoption framework discussed in Section 9.2 and presented in Figure 9.3. This duplication is deliberate and designed to encourage providers to have the answers to the items raised in the adoption framework readily available, for example return on investment, data use and ownership and connectivity requirements. .

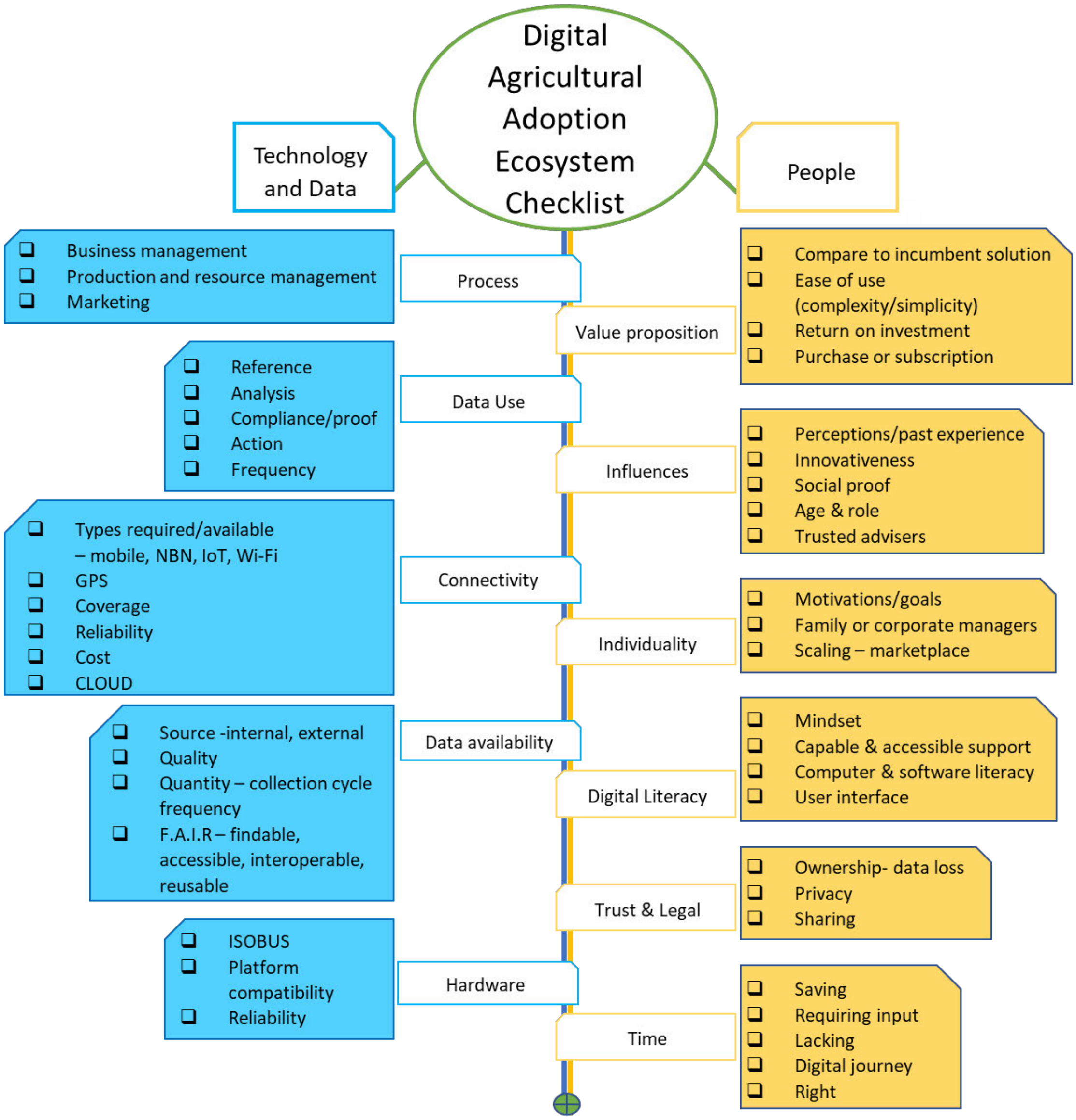


Figure 9.2

The DA Adoption Ecosystem Checklist

Note. The checklist is presented as a hierarchy of needs. Products and services need to address issues from top to bottom. Factors that need to be resolved will vary with product/service, but all need to be considered before outputs are provided to potential users.

9.1.3 Summary Section 9.1

In this first part of the discussion, factors supporting and impeding digital adoption have been discussed in relation to three supporting research questions. The factors impeding adoption have been condensed into two areas: 1) failing to consider digital solutions from the perspective of its role in a digital process and 2) failing to align solutions to an individual's aspirations. The DA adoption ecosystem checklist and its use to develop more relevant digital solutions and address these two areas of failing was presented. The factors impeding change to digital solutions that the adoption frameworks needed to address are as follows:

- clarify the value of a digital change in relation to a process and goals
- identify current level of digital skills and process
- capture individual priorities and align to business goals
- support change leadership and the implementation of the change
- identify solutions that provide value by delivering process change
- build confidence in digital solutions
- be time efficient to use and provide direction.

9.2 How an Adoption Framework Can Help

The complexity of the DA ecosystem and need to reveal the value proposition for digital change at an individual level, as discussed in Section 7.2, indicates the potential for a support framework to assist adoption decisions and implementation. Indeed, participants asked for a *proven pathway*, but this pathway needed to meet their specific needs. A one size fits all digital solution was repeatedly stated not to be an option. Providers believed that adoption support needed to help people go through a journey that was tailored to their particular needs, type of farm and environment. The family farming business, with small numbers of individuals engaged in a diverse range of tasks, brings specific people issues to adoption as reflected in the DA adoption ecosystem checklist (Figure 9.2). These specific needs all negate the success of traditional top down ‘show and tell’ extension activities such a s workshops, field days and demonstrations to change practices but only to raise awareness and increase knowledge (Pannell et al., 2011; Rogers, 2003)

When creating a DST to meet diverse criteria, the outputs can become too general and of little value. Research has noted reluctance in relation to ongoing use of DST, with users often reverting to intuitive decision making (Long, 2013). Part of this reluctance is associated with the completion of the DST requiring information that is beyond the tacit knowledge gained from experience and observation (Evans et al., 2017), or lacking specialised support (Eastwood et al., 2012). All these factors were considered embraced in the co-development approach of the components of the adoption framework.

The design of the adoption framework aimed to support the digital journey for an individual farm and its team members using familiar language. The framework provides an adoption learning and planning process driven by the farming business, i.e. from the bottom up, with the starting point being a task or process selected for change. The three parts of the adoption framework are the 1) DKSA; 2) the DPM; and 3) the Change Guide (Figure 9.3) can be used in varying combinations, or even in isolation. The evaluation tools are a unique feature not found in other adoption frameworks, although their requirement is acknowledged in adoption models focused on planned behaviour, technology acceptance and satisfaction (Oscar Montes de Oca et al., 2021). The evaluation tools require only tacit knowledge for their completion (Appendices F and G), while the change guide requires explicit knowledge and can be more aligned with a DST or task-technology fitness adoption model (Oscar Montes de Oca et al., 2021).

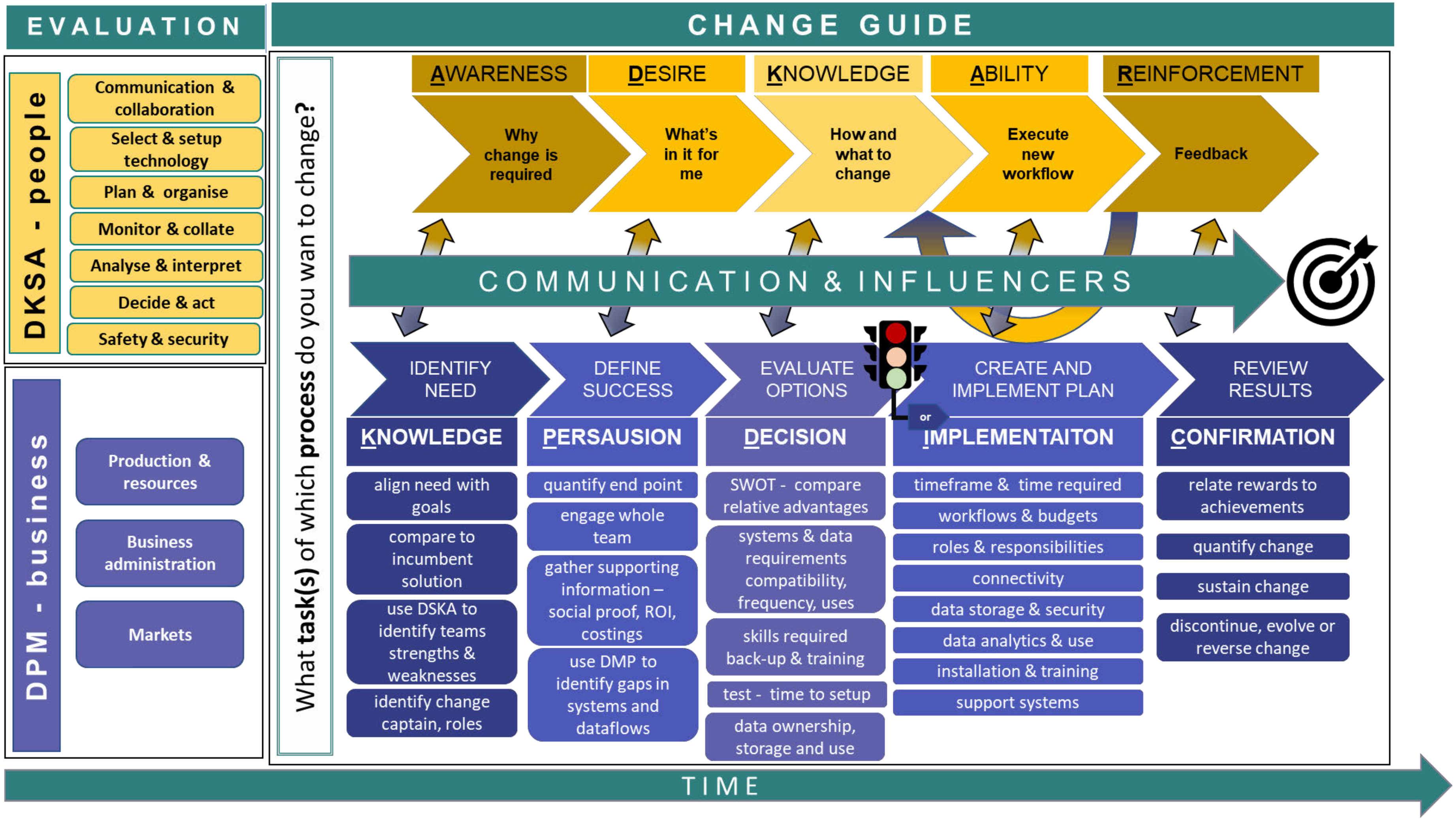


Figure 9.3

The Fully Developed DA Adoption Framework Indicating the Three Parts

Basing the evaluation tools around maturity modelling and populating them with task and situation statements specific to broadacre crop and livestock production delivers outputs relevant to an individual or business. However, as the name states, DST do just that: they support decision making; they do not make the decision. Returning to the journey analogy, the evaluation tools identify the starting point for a specific business and the change guide is the route planner for a selected technology or process change. All parts of the framework enable the journey's progress to be checked in relation to change goals. While the design of the adoption tool aimed to mitigate the reported failings of previous DST, its successful use still relies on the dedication of a 'change captain'. Some will use it as a signpost, others as a detailed itinerary. By drawing on change management theory the adoption framework addresses goes beyond meeting the three key elements for an adoption framework identified by Oscar Montes de Oca et al. (2021).The change guide provides a structured approach to evaluating technology selection and enabling implementation and the approach to engaging all members of the business team with this knowledge, factors considered essential for successful, embedded change (Hiatt, 2006). Consequently, the successful use of the adoption framework is bound to the appointment of a change captain. The family farming businesses were not used to such specific appointment of roles, which suggests the framework needs to be delivered as part of a supported extension package designed to facilitate bottom up approaches to change.

9.2.1 The Evaluation Tools

The evaluation tools were specific to digital change, being designed to identify and quantify the current state of digital knowhow of team members and of digitisation of processes of the business. Each tool can stand on its own merit but used together they provide greater insights into the human and technology sides of the DA adoption ecosystem in relation to an individual family farming business. The design of the evaluation tools facilitated speed over exactness to identify areas of strength and weakness in digital capability or process. Each evaluation tool was found to be time efficient, with respondents reporting a mean completion time of ~10 minutes for the DKSA and the software recording a mean completion time of ~16 minutes for the DPM.

With repeated use, the evaluation tools can be used to monitor change over time at an individual or business level. A farming business would need to interpret the importance of strengths and weaknesses in relation to an individual's role and responsibilities, and to incumbent solutions. This interpretation would be assisted if providers supplied information about their digital products and services aligned to the seven skill sets used in the DKSA and the people elements of the DA adoption ecosystem checklist.

Members of the teams appreciated the time efficiency of the tools and that they were based on tacit rather than explicit knowledge. They especially liked that each tool concluded with a quantified result they could use for comparison and to highlight strengths and weaknesses in skills and characteristics. The tool outputs were valued as talking points at family meetings and when starting to make decisions about digital investments or job descriptions. They also noted the results made them consider aspects of their business and team in new ways. For example, Team 4 stated:

> Seeing those questions that you have put together it made me think 'yes, that could be useful'. It has given me a bit of insight into what is possible. And also showed me that we are a long way from it, but it is something worth thinking about.

The teams identified three specific uses for the DKSA, as detailed in the following sections, with the third client evaluation also valuing the use of the DPM.

9.2.1.1 Evaluation and Comparison of the Digital Competency of the Internal Team Members

Team members found the DKSA results helped reveal new knowledge and understanding of the digital competency of their business team. Several teams illustrated that the scores gave them confidence, especially when they compared favourably with the scores of those they considered to have greater digital capability. Team 1 felt that without such a tool, ‘you can only guess at your ability based on what others in team know’. Others reported the total score confirmed what they knew but appreciated the breakdown by the three characteristics of knowledge, ability and attitude, as this illustrated the weight placed on each and where improvements could be made. They considered the DKSA improved their understanding of the skill sets required, how well each was developed and where further use of skills or training needs existed. A Manager in Team 2 noted about his DKSA score: ‘it’s a bit worrying that on “plan” and “organise” I am the lowest and I probably do most of the planning and organising’. Both Managers in Team 4 reported being unaware of the high level of digital ability and enthusiasm of their employee for digital technology until he had completed the DKSA: ‘that is a conversation we need to have, so that [score] is good to know’. The DKSA could be used before and after training exercises, and to select a change captain, and allocate roles and responsibilities.

9.2.1.2 Employment

Teams considered the DKSA to be especially relevant when designing job descriptions and evaluating potential employees. Participants reported that the DKSA helped them consider the skills they required in future employees and offered a way to evaluate these skills as part of the recruitment process. In the exit interview, Team 1 stated they would definitely use this type of tool when recruiting because, ‘we want to know their strengths and make sure they were being valued’. Team 5 felt the results offered ‘a two-way street; they would also be able to see what we expected in them’. However, Team 3 considered this type of approach was only relevant with a large number of employees: ‘if you had a team of 50 people, this would be extremely useful’. This perspective indicates the need for support and extension to demonstrate the value of using structured approaches in a family farming businesses (Hubler, 2009).

9.2.1.3 Client Evaluation

The Trusted Advisers involved with the exit interviews considered the DKSA and DPM would have uses for their clients. For example, the Trusted Adviser in Team 5 said, ‘I need to digest and work out how to present this to clients; I might use part of this process to get the family into a space to get it [change] to actually happen’. Another felt the DKSA helped them put a client’s digital skills into perspective and to better understand where assistance was required. These real-world examples suggest that Trusted Advisers would use the DKSA as part of their client services tool kit.

The assessment of the DPM was limited by issues with the platform and the questions not being sufficiently discrete, and embodying multiple rather than single issues. However, the participants were open to the concept of this tool, even though it took on average 6 minutes longer to complete than the DKSA. Generally, there was more interest in identifying which processes were considered digitalised than in the overall maturity score. Considerable inconsistency was recorded between team members’ responses regarding the current and desired state. Being able to record these differences was considered useful by the participants in family business discussions.

Team members also found the visualisation of the consistency or inconsistency of their choices valuable (Figure 8.11), even though these were distorted by failings in the survey design. However, the Trusted Adviser in Team 5 felt the level of detail from the whole tool required discussion to be confined to a single issue at a time, not the whole set of results: ‘you would probably just focus on one issue at a time with a farmer, I would say’.

The DPM helped confirm satisfaction with the current digital status of some focus activities: ‘that means we are happy where we are; that’s what it is, and I think that is what it should be’ (Team 3). The DPM was also seen as a way to clarify which data streams were required to help overcome data overload and move away from what was considered the current approach, as the Trusted Adviser in Team 5 stated, ‘you just start collecting data for the sake of data collecting, but nobody asked, what do we really need to make the decision’. The Trusted Adviser in Team 2 considered the DPM helped broaden his perspective on his clients’ priorities across their whole business: ‘it’s so easy to get focussed on what I can see is valid and what I am looking for but it’s really good to have that sort of levelling component of where it sits in the priorities of a farm manager’.

It had been envisaged that the DPM would be applied to the whole business, but users suggested they might apply it at an enterprise level; indeed, this might be easier as the current state of digital activity could vary considerably between enterprises. Such variation in digital maturity could be because of a difference in staff attitude as well as suitability of the digital solutions currently on the market. In running the tool by enterprise rather than the whole business, comparative scores could be produced to identify differences between enterprises in digital maturity. Such information would be hidden if the tool were used for the whole business. The fact that participants proposed alternative applications was viewed as a positive endorsement of the DPM.

Overall responses to the DPM were positive but several limitations with the current design were found, in addition to the previously noted issues with the survey tool. The DPM did not differentiate between data attributes relating to time and frequency of collection or data use. For example, for spray application, compliance records required four weather attributes—wind speed, wind direction, temperature and humidity—to be recorded during an application period. In the DPM, the single dataset of weather could be selected as digitised but that might only be an automated recording of rainfall, for example, not the four weather parameters of interest for spraying. Similarly, all data were considered equal in terms of recording and longevity of records. For example, when planning a spray operation, predictions of rain and wind were checked, but there was no requirement to record these weather data; they were only referenced for planning. Achieving these additional layers of detail may be difficult to deliver in the DPM. Consideration of these issues of data types, use and collection frequency is included in the expanded action points in the Change Guide that summarises issues that emerged from the literature and data collection (Figure 7.3).

Before wider testing is initiated, further rounds of small-scale testing are required to address these issues. An alternative approach to validation should be concurrently tested. The current validation questions were aligned to the core functions, but it is considered that alignment to focus activities would make them more discrete and easier to compare with selections in the tool.

9.2.1.4 Change Guide

The Change Guide provides a structure to harmonise the knowledge, understanding and implementation of a proposed change by all parties in the farming business. In this research, it was used to draw out individuals' ideas for digital changes. The steps in the Change Guide were also used to illuminate the subthemes in the analysis of the commercial interviews, helping to draw together the data collected from the two participant groups in this research.

The elements of the guide addressed with participants were the fundamental steps of identifying a need, appointing a change leader and identifying the reasons and benefits for change. While the teams did not fully test the Change Guide, they acknowledged the value of parts of the guide with which they interacted. Younger family members saw the use of the guide as a valuable way to encourage senior members to share their experiences and facts that informed their decisions. A senior family member stated, 'as you get more experience, a lot of stuff becomes second nature in the planning and organisation'. The response from the junior member was, 'that's a massive problem'.

The core steps of the Change Guide can be applied to any change, greater detail is required to enable a specific digital change. To address a digital change, five checklists were aligned to each step of the innovation decision, and they consist of factors identified in this research and wider literature to influence digital change (Figure 9.3). Since establishing the conceptual adoption framework and populating and testing the three elements, two new adoption models specific to precision and digital technology have been reported (Eastwood & Renwick, 2020; Rojo-Gimeno et al., 2019). Each of these new models offer additional approaches to address items in the evaluating options checklist. The value of the Change Guide for a digital change was acknowledged but not fully tested by the participants. The lack of a strategic approach to change implies that the use of the Change Guide, indeed the whole adoption framework, would require support. To gain traction with the farming industry it is proposed the adoption framework would benefit from being incorporated into a targeted extension program for adoption of DA that are designed to support a bottom up approach to adoption using a change management approach.

9.2.2 Summary Section 9.2

The discussion in Section 9.2 specifically addresses RQM. Considering the small number of members in each Farm Business Team, it is easy to assume that communication would occur, yet the lack of consistency of priorities between team members recorded in this research indicates on-farm communication needs support to improve clarity and comprehension. Several participants reported the value of the adoption framework helping them to 'see what the others were thinking'. It helped them work as a team rather than individuals: 'it certainly made us think and there will be some discussion. It has made us think and focus a bit more'.

While the use of a DST has limitations, the positive feedback by the teams on the three-part adoption framework subjectively validated the use of the evaluation tools and Change Guide to support digital change by family farming businesses. Establishing the framework on the theories of change management and diffusion of innovation, and on maturity modelling, helped mitigate the limitations experienced by previous DST relating to requiring considerable time and information for their completion. However, change management introduced the concept of requiring a change captain to deliver successful change, which was unfamiliar to the family farming businesses.

Consequently, to achieve uptake of the change management approach and supporting adoption framework the provision of training and extension is suggested.

The following key benefits were reported by the participants from the use of a DA adoption framework:

- quantification of the current state of digital knowledge and process
- identification of strengths and weaknesses in digital knowhow and process
- relationship of strengths and weaknesses with a specific digital change
- implementation of a proven pathway for adoption
- a communication tool to engage and guide the whole team to achieve a common goal.

The aim of the research was to evaluate the use of a framework to improve adoption of DA by a family farming business. To achieve this, a framework had to be constructed and its appropriateness and content validity assessed by potential users. In the course of the research, it was confirmed that both providers and potential users of DA solutions continued to lack clarity on the value propositions from digital changes. Consequently, a DA adoption ecosystem checklist was also developed. By delivering a reference structure for providers to help stimulate dialogue with users, the ecosystem can help ensure digital products and services address adoption factors from a human and technological perspective. Some adoption factors appear in the ecosystem and the adoption framework. In this way, it is hoped that developers and providers will produce resources to provide the specific information required by a Farming Business when making decisions about DA adoption.

9.3 Summary Chapter 9

This discussion has identified that a new approach to adoption is required for digital solutions because of their complexity and the interconnected nature of individual technologies used to execute tasks within a process. The approach proposed is inclusive of both providers and users of digital technology in the development, delivery and implementation of a digital solution. It proposes that both parties consider digital change from a people and process perspective rather than the task and technology perspective currently applied. The DA adoption ecosystem checklist and DA adoption framework were designed to support a process change approach; the former for developers and providers, the latter for farming businesses. These tools were designed to help both parties identify and articulate the value proposition of digital solutions. The mirroring of elements within both frameworks aimed to ensure the information required by users to make an adoption decision is provided in an appropriate and relevant format by providers.

The conclusions drawn from these research findings, together with the limitation of the research and opportunities for further investigation, are reported in Chapter 10.

Chapter 10: Conclusions

This final chapter presents the conclusions to this research in relation to the specific research questions. It also summarises the potential significance of this study, its limitations and opportunities for further work.

DA combines two complex systems—digital and agriculture—with a third: people. Two clear gaps within the literature emerged:

1. the lack of appropriate guiding frameworks designed to support DA adoption by family farming businesses.
2. little understanding of the commercial point of view on DA adoption.

Family farming businesses were the focus of this research because this is the dominant farming business structure in Australia. Moreover, family businesses have different needs from corporate businesses when addressing change. However, the embedding of providers in the research gave an alternate perspective on the adoption barriers and confirmed that both providers and potential users of digital solutions were struggling to identify a value proposition.

The overarching conclusion of this research is that the value proposition for DA adoption will only be delivered when:

1. potential users can better articulate their digital needs and wants
2. digital solutions are presented as part of a digitalised or digitally transformed process
3. digital solutions consider the personal aspirations of family farming businesses
4. targeted extension and competent support is available to guide and execute the digital journey.

10.1 Conclusions—Sub-Question RQ1

What are the fundamental components of digital agriculture for grain, livestock and mixed farming businesses?

The following points provide the key learnings in relation to understanding the current status of digital adoption and the attitudes of the team members to DA solutions. From these the fundamental components of DA were extracted:

- The digital technologies adopted were dominated by those not specific to agriculture (73%). Farm management software and enabling technology such as autosteer and rate controllers were the only agriculture-specific digital technologies used. This compared with the sophisticated digital processes that the farming teams wished to adopt if the value proposition and technology to were available. These research results reflect the immaturity of DA adoption based on limited use of digital technologies (Chapters 5 and 7).
- This lack of uptake of agriculture-specific technology is seemingly at odds with the views of institutions, investors and providers when it comes to the perceived opportunities and benefits of DA (AgFunder, 2020; Trendov et al., 2019). Policy and funding is very technology centric, often overlooking other options and the socio-ethical influences. Failure to realise these benefits on farm occurs because of a combination of human perceptions around adopting the technology, including the lack of clear value propositions (Section 5.1.5).
- In this research, lack of connectivity and trust in sharing data were not found to be the predominant impediment to adoption, as is often presented in the literature (Chapter 2 and Sections 5.1.and 6.2).
- Adoption remained ad hoc and unstructured the teams in this research despite them being innovative and possessing a positive perception of the benefits of DA for production and profit. No teams reported having strategic or

operational plans for even the first level of digital transformation, namely the digitisation of data. Teams had limited to no ability to articulate their current digital capability in terms of processes and people (Sections 7.1 and 7.2).

These points suggest that the fundamental components of DA are digitised data in interoperable formats that integrate systems to deliver fully digitalised workflows. All these elements must be easy to use and useful if value is to be provided to family farming businesses that lack skills, time and specialist support. The fundamentals of DA adoption must consider the technology in relation to the process and user wants and needs. However, the potential user must have the mindset to change and the level of support required to implement the change. Therefore, the fundamental components of DA adoption relate to technological and human influences.

10.2 Conclusions—Sub-Question RQ2

Why and how do farm businesses initiate the use of digital technologies for farm management and how could this be supported by a change management approach?

The conclusions in this section build a picture of how and why adoption or rejection of DA occurs. Technological and human influences were considered specifically in relation to implementing a change management approach:

- All Managers and Trusted Advisers agreed that adoption occurred when technology directly met a need, and 7/8 of Managers perceived DA to offer productivity and profitability benefits (5.1.3).
- Ease of use was considered essential (8/8 Managers), with a clear value proposition strongly influencing adoption by 6/8 of Managers. This indicates that facility and utility of a DA technology are key components of the value proposition (5.1.5).

- DA adoption often was accelerated to engage the interest of younger members the family in the farming business. Other influences were those of trusted farmers and advisers and the lead of suppliers (Section 5.1.5).
- Team members shared responsibility for adoption activities, rather than appointing a change captain (Section 7.2).
- Adoption was curtailed because of previous negative experiences with, or perceptions of, digital solutions. Negative perceptions included adoption taking too much time, lack of confidence in the technology and their skills, loss of control of data and lack of value (Chapter 5).
- The lack of perceived value proposition was due to current digital solutions failing to offer considerably more than incumbent solutions, specifically in relation to lack of interoperability and delivery of digital workflows. This latter point was again reinforced by the sophistication of the processes that team members wished to digitise. These processes required integrated hardware and interoperable data rather than stand-alone products and data siloed in proprietary systems (Sections 7.1 and 7.3).
- As digital technologies were adopted to meet a need, this resulted in a task-based rather than a process-based approach to delivery and use (Chapters 5 and 6).

Because of the complexity of DA, the current ad hoc nature of adoption and the specific needs of family farming businesses, an adoption framework was considered an appropriate way to overcome DA adoption barriers. Based on the theories of change management and diffusion of innovation, and on maturity modelling, a framework was designed to support a methodical approach suited to on-farm use. To be acceptable, the framework needed to be quick and easy to use, provide direction, and encourage input from all team members. Maintaining a focus on people and the process to be changed by the business, rather than the technology to achieve the change, was recognised as crucial for successful adoption and became the driving force behind the framework. Moving from a task to a process focus is considered vital in the development of appropriate DA technologies and services that support data flows along the value chain and in the delivery of clear value propositions for DA adoption.

10.3 Conclusions—Sub-Question RQ3

How do commercial providers of digital agricultural hardware, software or support services, view and address the barriers to uptake of digital agriculture?

The commercial providers of digital technology and services are a vital part of the adoption journey. Lack of understanding of the commercial providers perspective on adoption was identified as a clear gap in the literature and was addressed by an embedded study. The following conclusions help fill the knowledge gap relating to the experience and perceptions of providers of digital solutions to agriculture.

- Engaging with providers of digital technology and services to agriculture provided unique insights into the supply side of DA adoption. Providers acknowledged that people, not the technology, are at the heart of DA adoption. However, their interviews identified that the provider focus and approach to adoption was dominated by promoting the functions and applications of the technology (Section 6.2, Figure 6.5).
- Suppliers indicated frustration that potential users did not see the value in their technology or technology-based service, or did not want to invest money or time in its use. These providers recognised that lack of a clear value proposition remained a barrier to the adoption of DA, with almost 80% placing this in their top three barriers to adoption (Section 6.1).

- The ongoing negative influence of the other five barriers was recognised and all influenced the perception of value proposition. In addition, four other barriers were identified: time, individuality, influences and the need for an ecosystem. Despite the interrelationship between all these barriers, none of the providers delivered a systems or process approach to support digital adoption. Their main methods to support DA adoption were the use of case studies and free trials (Section 6.2).

The DA adoption ecosystem was built on the 10 barriers to adoption and the factors underpinning each barrier. It identifies human, technology and data factors that need to be considered by developers and providers of DA products and services. Based on providers responses, the ecosystem was developed into a hierarchical checklist to help developers and providers systematically address all factors that might influence DA adoption. To this end, a process approach to DA technology was added to the checklists (Figure 9.2). Some items in the DA adoption ecosystem checklist are mirrored in the DA adoption framework. This replication of items was designed to encourage providers to deliver information to address issues raised in the decision and implementation steps in the Change Guide. Access to clear, detailed and specific information on a DA solution would help reveal its value proposition to a potential user.

10.4 Conclusions—Main Research Question

How can an adoption framework improve uptake and use of digital agriculture by a family farming business?

The conclusions in the section draw on the answers to the sub-questions, and the development and testing of the DA adoption framework by the teams:

- Formalised systems thinking was uncommon in family farming businesses, despite them reporting being time poor. Consequently, the use of a process and change management approaches to DA were unfamiliar (Sections 5.1.5 and 7.3). Engaging all team members and placing people rather than technology as the focus of the change was positively received (Section 9.3).

- The three parts of the adoption framework—1) DKSA; 2) DPM; and 3) Change Guide—were subjectively assessed and shown to be appreciated by the teams according to positive sentiments expressed in the feedback and exit interviews (Chapters 5 and 8, Section 9.3).
- The three-part framework melded theories of change management, and diffusion of innovation and maturity modelling. The individual parts helped break down the complexity of digital adoption by isolating issues of capability, current and desired process. The quantification of these elements with the whole team identified strengths, weaknesses and differences in objectives and perceptions. In so doing, one of the key *change success factors* was delivered: having everyone working to a common goal. With greater knowledge of these influences within their own business, more appropriate decisions can be made (Chapter 8).
- Lack of time is a major impediment in family farming businesses. The first parts of the adoption framework (the evaluation tools DKSA and DPM) were designed to return robust indications of digital knowhow and process. Favouring speed over exactness, the DKSA and DPM proved acceptable to the teams as quick and easy to complete and in providing insights about the digital state of their team and processes (Chapter 8, Section 9.3).
- The teams reported the benefits they gained from the DKSA scores and that the score could be presented according to skills and characteristics, providing them with specific areas of strength and weakness. A key benefit reported was the ability to compare DKSA scores between team members, which provided

an individual with confidence in their ability and guidance on areas for improvement (Section 8.1.3).

- The ability to compare team members' perceptions of the current and desired state of digital process using the DPM was valued more greatly than the overall maturity score. The DPM design requires further refinement, but the teams appreciated that it supported digital adoption at a process rather than technology level (Section 8.2.3).
- The duration of the research only allowed the teams to test parts of the Change Guide with an unconstrained (desired) digital change scenario, rather than a genuine example. The Change Guide provides steps and checklists to help navigate the change and involve the whole family farm team, which was viewed positively in terms of providing direction (Section 9.3.2).
- Mirroring of factors from the DA adoption ecosystem checklist in the adoption framework was intended to help developers and providers deliver the information and solutions required to support the adoption decision and eventual implementation of a digital change. In so doing, the ecosystem and framework can improve two-way dialogue, unlock the value propositions for both parties and create a bridge to overcome the agtech disconnect (Chapter 9).
- Because of lack of familiarity with change management and the complexity of digital change, the use of the adoption framework is considered to require support via a trusted adviser or an appropriate extension program (Section 7.3).

The outputs of the evaluation tools were considered to provide valuable insights before initiating a change and were considered useful for guiding family discussions regarding digital adoption. However, if family farming business are to unlock their value position for DA, they need to be able to articulate their needs to developers and providers of digital solutions. By couching these needs in terms of workflows rather than tasks, digitalised and digitally transformed processes will be developed and the true value of digitalisation can start to be delivered on farm.

The overarching conclusion of this research is that a new approach to adoption is required for digital solutions. This approach will need to be supported by extension and to:

- consider digital change from a people and process perspective rather than the task and technology perspective currently applied
- be inclusive of both providers and users of digital technology in the development, delivery and implementation of a digital solution.

10.5 Significance of the Research

The literature review identified two gaps that have been addressed by this research: a lack of decision support or evaluation structures to guide family farming businesses in their adoption of DA; and a lack of understanding of the commercial perspective on DA adoption. The research question and sub-questions addressed these issues via a mixed methods approach. The layering of the qualitative and quantitative data gathered from the two populations of participants, family teams and Commercial Providers, produced rich insights into their perspectives on adoption of DA. These insights resulted in the production of the DA adoption ecosystem and elements of the Change Guide.

The small sample size enabled the researcher to undertake work closely and repeatedly with the teams and build trust with the participants, using multiple approaches to remote data collection. Using an iterative approach to gain consensus of content, the participants provided subjective validity of the evaluation tools, the first two parts of the DA adoption framework. However, the design of the DKSA was such that construct validity can be statistically tested with a larger sample. With minor modifications, the DPM would also be suited for wider statistical testing.

Two elements of the approach to this research deserve specific consideration in their contribution to the significance of the results: (i) working with teams rather than individuals, and (ii) the use of video tutorials. Most academic research on on-farm adoption has involved the primary member of the family farming business. To capture the important but often subtle undercurrent of influence within family businesses, this research worked with multiple members of the internal family farming team, as well as their nominated external trusted adviser. This team approach highlighted the known individualist nature of the family business (Fulton & Vanclay, 2011) by revealing inconsistencies between team members' responses and priorities. If the research had solely been reported against data collected from one rather than multiple members of the family farming business, the results would have been distorted and the diversity of capability would not have been captured. Clear differences between preferences, and even factual data reported by Managers in the same team, illustrates the misinterpretation that could have occurred. Adoption success is controlled by people, not by the technology or change. Understanding and accommodating these inconsistencies and differences in perspective are fundamental to successful adoption. The value gained from using this team approach in relation to an adoption study cannot be overstated.

Use of video tutorials offered many advantages, especially when working with remotely located participants with a wide range of skills and knowledge. The videos provided a way of sharing knowledge and informing with participants in different roles. This delivery was at a time suitable to the individual and videos could be reviewed as required, asynchronously. The addition of the open question specific to each video enabled focussed data collection from an individual team member. Data collection did not use a social media platform because privacy of response, even between team members, was required. The videos gave the opportunity for the researcher to present updates personally, rather than using the less personal approach of written reports. The use of the videos supported the ongoing engagement of all participants, which was reflected in the level of detail supplied in response to the questions.

10.6 Limitations

While working with teams was one of the key benefits of this research design, recruiting complete teams proved challenging and resulted in a small sample size. Nonetheless, the small sample size was suited to the iterative development process deployed in this work, even if it meant subsequent statistical analysis was limited to descriptive statistics. This lack of statistical analysis was offset through validation questions to indicate appropriateness of the scoring system. Similarly, the layering of multiple sources of qualitative data and use of consensus approaches supported the production of a framework acceptable to farming businesses and trusted advisers. As no such adoption framework for a family farming business to adopt digital technology existed, no comparison of scoring systems or structure could be made.

The limitations of the formatting of the survey tool for the DPM and the issue of some statements containing multiple rather than single issues was presented in the discussion. While the former limitation prevented accurate collection of data, the design was acknowledged as appropriate and enabled differences between team members' perceptions of the digital process to be visualised.

The outputs of the DKSA and DPM took considerable time to analyse and produce as easily interpreted visualisations. Ultimately, scores and outputs need to be quickly produced and presented as a change management guide linked to a digital change nominated by a farming business. Provided that wider statistical testing of the framework returned encouraging results, alternative data collection and analysis platforms would be required to deliver the framework as a farm management tool.

10.7 Recommendations for Further Research

The development of the evaluation tools and Change Guide with direct input from farming businesses provided an adoption framework acceptable to that target audience. The facility to quantify the current state was particularly appreciated. However, this was the subjective response of a small development group. To ensure construct validity of the evaluation tools, wide-scale testing using explanatory factor analysis and at least 400 participants in two study cohorts is required. This sample population estimate is based on the use of the Yamane equation to establish statistically significant sample size (Davies, 2020) for Australian broadacre and mixed farming. Prior to the occurrence of such testing, further pilot testing of the platform, questions and validation approach for the DPM is required. Only parts of the change Guide were tested. Experience from this research indicates that testing the Change Guide needs to start with a task in a process that the farm team wishes to digitise. The assessment of the use of the adoption framework as part of a digital adoption extension program offers another area for further investigation. The use of a ranked scoring system in some questions in the DKSA appeared to disproportionately increase some participants' scores. There is an opportunity to reanalyse data with alternative scoring systems before wide-scale testing.

The adoption framework was designed to meet the needs of family farming businesses working in broadacre grain and livestock production. The initial testing of the evaluation tools suggests it has achieved an appropriate scoring system and acceptable structure. The structure and components of the adoption framework could be tested with other industry sectors, but a set of sector-specific task and situation statements would be required.

The lack of objective and critical analysis of adopting digital solutions compared to maintaining the status quo or adopting non-digital solutions was identified as an important gap in the literature. Issues of management of on-farm cyber security, a problem that received minimal attention in this research could be addressed by specific research or within a critical analysis.

The DA adoption ecosystem checklist was an additional output from this research. An assessment of the role of the ecosystem, alone or with tools such as ADOPT (Kuehne et al., 2011), in the development of digital solutions with improved value propositions, is another potential area of research.

10.8 Implications

The outcomes of this research illustrate that barriers to digital adoption remain and that potential users are confused and cautious about investment for a range of reasons. The value of digital solutions remains unclear to both providers and potential users of them. Family farming businesses lack formal recognition of the current status of digital knowhow of team members and processes. In short, adoption of DA remains ad hoc.

The adoption framework is the first decision support system (DSS) designed to guide on-farm adoption of DA by family farming businesses. Designed with substantial input from potential users, the evaluation tools meet the criteria of being quick and easy to complete using tacit knowledge, and provide quantified results to support adoption decisions. The repeated use of the evaluation tools enables change over time to be recorded. Results from these tools feed into the Change Guide, which encourages systems thinking, highlighting key factors that need to be addressed at each step of the journey and supporting whole team engagement. Consequently, the three-part adoption framework provides a DA-specific DSS that embodies formal business processes in a format suited for use by a family farming business. In so doing, the framework enables a business to identify its own value propositions from a digital change. This is the first time that farming businesses have been provided with such a tool to support DA adoption.

The value proposition for DA can only be realised by users if developers and providers can produce and deliver appropriate DA solutions. In combination with the DA adoption ecosystem checklist the DA adoption framework supports a new approach to DA adoption. This approach embraces both providers and users and takes a people and process perspective rather than the current task and technology approach. For successful implementation, this new approach will require extension support.

While final refinements and wide-scale testing are required, the adoption framework provides a simple, yet powerful systematic approach to digital change. The framework is suited for use by a farm business team, adviser with clients or as part of a digital adoption of change management extension program. The outputs from this research will be shared via the SmartFarm Learning Hub an open-access website hosted by the UNE that provides training packages in DA technologies.

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Appendices

Appendix A: Ethics Approval

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New England

Ethics Office
Research Development & Integrity
Research Division
Armidale NSW 2351
Australia
Phone 02 6773 3449
Fax 02 6773 3543
jo-ann.sozou@une.edu.au
www.une.edu.au/research-services

HUMAN RESEARCH ETHICS COMMITTEE

MEMORANDUM TO: A/Prof Sue Gregory, Dr Fran Cowley, Prof David Lamb, Dr Reuben Wells & Ms Emma Leonard

School of Education

This is to advise you that the Human Research Ethics Committee has approved the following:

PROJECT TITLE:	Overcoming the barriers to adoption of digital agriculture
APPROVAL No.:	HE18-200
COMMENCEMENT DATE:	15 August, 2018
APPROVAL VALID TO:	28 February, 2021
COMMENTS:	Nil. Conditions met in full

The Human Research Ethics Committee may grant approval for up to a maximum of three years. For approval periods greater than 12 months, researchers are required to submit an application for renewal at each twelve-month period. All researchers are required to submit a Final Report at the completion of their project. The Progress/Final Report Form is available at the following web address: http://www.une.edu.au/research/research-services/rdi/ethics/hre/hrec-forms

The NHMRC National Statement on Ethical Conduct in Research Involving Humans requires that researchers must report immediately to the Human Research Ethics Committee anything that might affect ethical acceptance of the protocol. This includes adverse reactions of participants, proposed changes in the protocol, and any other unforeseen events that might affect the continued ethical acceptability of the project.

In issuing this approval number, it is required that all data and consent forms are stored in a secure location for a minimum period of five years. These documents may be required for compliance audit processes during that time. If the location at which data and documentation are retained is changed within that five year period, the Research Ethics Officer should be advised of the new location.

Jo Sozou.

Jo-Ann Sozou
Secretary/Research Ethics Officer

15/10/2020 A18/54

Appendix B: Information Sheet and Consent Form for Participants

une University of New England

School of Education
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Armidale NSW 2351
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INFORMATION SHEET for all PARTICIPANTS

Thank you for responding to my invitation to participate in my research project as describe below. This information is for potential participants in any of the three groups that will make up participating business teams - owner/manager, junior manager/employee and advisor.

My name is Emma Leonard and I am conducting this research as part of my PhD in the School of Education at the University of New England. My supervisors are Associate Professor Sue Gregory, Dr Fran Cowley, Professor David Lamb and Dr Reuben Wells.

Research Project	**Overcoming the barriers to adoption of digital agriculture**
Aim of the Research	Using a more planned and structured approach, can farming businesses be better able to adopt digital technology? And can working together, within your business team (including external consultants/third party service providers) and externally with like-minded farming businesses help you achieve better adoption of digital technologies? These are the issues this research aims to assess in relation to the question 'How can an adoption framework help improve the uptake and use of digital agriculture?' With agreement from all parties, this research will work with farm business managers and their interested junior manager/employee and third party service provider to test the use of a change management framework as a method to support a structured approach to the adoption of digital technologies by farming businesses. The creation of a change management plan supported by clear value propositions for digital technologies identified to be of interest to the farming businesses involved in the study will be an important outcome of this research.
Survey, interviews and group participation	I am hoping to recruit 20 farming business each with a business team consisting of an owner/manager, junior manager or employee and a third party service provider who works closely with the business. Involvement in this research can only occur with written agreement of the whole team. Each member of the business team will be required to share their experience, knowledge and opinions via an online survey and group interviews by video with the other members of their business team. Additionally, one self-nominated member of each farm business team will be required to join an online self-mentoring group with the nominated members from other business teams to work collaboratively on the adoption of a digital technology agreed by the group. If one member of the management team change or withdraw from the trial, after the completion of the survey and initial interview the business may remain in the trial providing the primary farmer/business manager has not withdrawn. All online involvement will be designed to be feasible on low quality broadband connections. **<u>Online Survey</u>** Each participant will be required to complete an online survey at the beginning of the project and repeat it at the end (August 2018 and approximately August 2019). Each survey will be tailored to the participant's role (manager, employee, third party service provider). Each survey is expected to take around 45 minutes.

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INFORMATION SHEET for all PARTICIPANTS

Recorded Interviews

Each business team will be required to participate in recorded interview, which may be followed up by two or three subsequent interviews for clarification over a two to three month period. Interview times will be arranged for your convenience and is anticipated to take about an hour. With your permission, I will make an audio recording of the interview to ensure that I accurately recall the information you provide. Following the interview, a transcript can be provided on request.

Each farming business participating in this research will receive a report to identify the current barriers to adoption of digital agricultural tools and the resources required to overcome these barriers.

From the information gathered in the survey and interview the digital technology that you are most interested in adopting will be identified. This will be the target of the next stage of the research.

Self-mentoring Groups

Following the initial phase of the research one member of your business team, nominated by your business team, will have the opportunity to participate in a self-mentoring farmer group that aims to support the adoption of the digital technology identified to be of interest by a number of businesses in the study. Group interaction will be approximately monthly for six to eight months by most likely by video conference but face to face if the groups desires and up to two hours per meeting.

Meeting agendas will be driven by the participants and linked back to their business teams change management plan.

Supporting the Change Process

A social communication platform will be used to provide a closed communication space for use by participants to help support the change process and share information. Input will depend on individuals.

In addition to meeting time, each participant would be required to commit one hour per month over 15 month period to implement adoption of the candidate technology in their business.

Confidentiality

Any personal details gathered in the course of the study will remain confidential. No individual will be identified by name in any publication of the results. All names will be replaced by pseudonyms; this will ensure your anonymity. If you agree I would like to quote some of your responses. This will also be done in a way to ensure that you are not identifiable.

Participation is Voluntary

Please understand that your involvement in this study is voluntary and I respect your right to withdraw from the study at any time without consequence and without needing to provide an explanation.

Questions

The Survey and Interview questions will not be of a sensitive nature: rather they are general, and will enable me to enhance my knowledge of your current use of digital technology and how this impacts on your business. Other questions would relate to your attitude, knowledge and skills, challenges and objectives in relation to adoption of digital technology.

Use of Information

I will use information from the survey, interview and focus group meetings as part of my doctoral thesis, which I expect to complete in August 2020. Information from the surveys and interview may also be used in academic journal articles and

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INFORMATION SHEET for all PARTICIPANTS

conference presentations before and after this date. At all times, I will safeguard your identity by presenting the information in a way that will not allow you to be identified.

Upsetting Issues

It is unlikely that this research will raise any personal or upsetting issues but if it does you may wish to contact Beyond Blue 1300 22 4636 or Lifeline on 13 11 14.

Storage of Information

I will keep all hardcopy notes and recordings of the interviews in a locked cabinet in my office at Urania, South Australia. Any electronic data will be kept on cloud.une.edu.au, UNE's centrally managed cloud server managed by the research team. Only the research team will have access to the data.

Disposal of Information

All the data collected in this research will be kept for a minimum of five years after successful submission of my thesis, after which it will be disposed of by deleting relevant computer files, and destroying or shredding hardcopy materials.

Approval

This project has been approved by the Human Research Ethics Committee of the University of New England (Approval No HE18-200, Valid to 15/08/2019).

Researchers Contact Details

Feel free to contact me with any questions about this research by email at eleonar3@myune.edu.au or by phone on 0428 894 069.

You may also contact my supervisors. My Principal supervisor's name is Sue Gregory and she can be contacted by email at sue.gregory@une.edu.au or by phone on 02 6773 5054, and my Co-supervisors' names are Fran Cowley, fcowley@une.edu.au, 02 6773 6164, David Lamb, dlamb@une.edu.au, 026773 3565 and Reuben Wells 0448 947 286, reuben@aglogic.com.au.

Complaints

Should you have any complaints concerning the manner in which this research is conducted, please contact:
Mrs Jo-Ann Sozou
Research Ethics Officer
Research Services
University of New England, Armidale, NSW 2351
Tel: (02) 6773 3449 Email: ethics@une.edu.au
Thank you for considering this request. I look forward to further contact with you.
To acknowledge your agreement to be involved in this study please complete the attached [redacted]

Regards, [redacted]

Emma Leonard

School of Education
University of New England
Armidale NSW 2351
Australia
~~Phone~~ 0428 894069
eleonar3@myune.edu.au

CONSENT FORM for all PARTICIPANTS

Research Project: Overcoming the barriers to adoption of digital agriculture

I, ..., have read the information contained in the Information Sheet for Participants and any questions I have asked have been answered to my satisfaction.	Yes/No
I agree to participate in this activity, realising that I may withdraw at any time.	Yes/No
I agree that research data gathered for the study may be quoted and published using a pseudonym.	Yes/No
I agree to having my interview audio recorded and transcribed.	Yes/No
I would like to receive a copy of the transcription of the interview.	Yes/No
I am older than18 years of age.	Yes/No

....
Participant Date

....
Researcher Date

Appendix C: Information Sheet and Consent Form for Commercial Participants

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eleonar3@myune.edu.au

INFORMATION SHEET for Commercial PARTICIPANTS

Thank you for responding to my invitation to participate in my research project as describe below. This information is for potential commercial participants that have expressed interest in sharing experience relating to the adoption of digital agriculture.

My name is Emma Leonard and I am conducting this research as part of my PhD in the School of Education at the University of New England. My supervisors are Associate Professor Sue Gregory, Dr Fran Cowley, Professor David Lamb and Dr Reuben Wells.

Research Project	**Overcoming the barriers to adoption of digital agriculture**
Aim of the Research	Using a more planned and structured approach, can farming businesses be better able to adopt digital technology? And can working together, within your business team (including external consultants/third party service providers) and externally with like-minded farming businesses help you achieve better adoption of digital technologies? These are the issues this research aims to assess in relation to the question 'How can an adoption framework help improve the uptake and use of digital agriculture?' With agreement from all parties, this research will work with farm business managers and their interested junior manager/employee and third party service provider to test the use of a change management framework as a method to support a structured approach to the adoption of digital technologies by farming businesses. The creation of a change management plan supported by clear value propositions for digital technologies identified to be of interest to the farming businesses involved in the study will be an important outcome of this research. I am hoping to recruit 20 farming business each with a business team consisting of an owner/manager, junior manager or employee and a third party service provider who works closely with the business. to be feasible on low quality broadband connections. More information on this part of the research can be provided on request. Identifying the barriers to adoption of digital agriculture is a key part of the foundation of this project.
Interviews	This information sheet relates to commercial businesses involved in digital agriculture who have responded to the invitation seeking farming businesses and their third parties to be involved in the research. Such businesses have valuable experience in dealing with issues of relating to the adoption of digital technologies and practices in the agricultural industries. By sharing their experience of adoption barriers and how these have been dealt with, it is proposed that a broader understanding of adoption barriers in Australian digital agriculture can be established and used to underpin the other parts of this research. **Recorded Interviews**

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INFORMATION SHEET for Commercial PARTICIPANTS

Each business will be required to participate in recorded interview, which may be followed up by two or three subsequent interviews for clarification over a two to three month period. Interview times will be arranged for your convenience and is anticipated to take about two hours. With your permission, I will make an audio recording of the interview to ensure that I accurately recall the information you provide. Following the interview, a transcript can be provided on request.

Confidentiality

Any personal details gathered in the course of the study will remain confidential. No individual or business will be identified by name in any publication of the results. All names will be replaced by pseudonyms; this will ensure anonymity. If you agree I would like to quote some of your responses. This will also be done in a way to ensure that you are not identifiable.

Participation is Voluntary

Please understand that your involvement in this study is voluntary and I respect your right to withdraw from the study at any time without consequence and without needing to provide an explanation.

Questions

The interview questions will not be of a sensitive nature: rather they are general, and will enable me to enhance my knowledge of your current use of digital technology and how this impacts on your business. Other questions would relate to your attitude, knowledge and skills, challenges and objectives in relation to adoption of digital technology.

Use of Information

I will use information the interview as part of my doctoral thesis, which I expect to complete in August 2020. Information from the interview may also be used in academic journal articles and conference presentations before and after this date. At all times, I will safeguard your identity by presenting the information in a way that will not allow you to be identified.

Upsetting Issues

It is unlikely that this research will raise any personal or upsetting issues but if it does you may wish to contact Beyond Blue 1300 22 4636 or Lifeline on 13 11 14.

Storage of Information

I will keep all hardcopy notes and recordings of the interviews in a locked cabinet in my office at Urania, South Australia. Any electronic data will be kept on cloud.une.edu.au, UNE's centrally managed cloud server managed by the research team. Only the research team will have access to the data.

Disposal of Information

All the data collected in this research will be kept for a minimum of five years after successful submission of my thesis, after which it will be disposed of by deleting relevant computer files, and destroying or shredding hardcopy materials.

Approval

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Researchers Contact Details

Feel free to contact me with any questions about this research by email at eleonar3@myune.edu.au or by phone on 0428 894 069.

You may also contact my supervisors. My Principal supervisor's name is Sue Gregory and she can be contacted by email at sue.gregory@une.edu.au or by phone on 02 6773 5054, and my Co-supervisors' names are Fran Cowley, fcowley@une.edu.au, 02 6773 6164, David Lamb, dlamb@une.edu.au, 026773 3565 and Reuben Wells 0448 947 286, reuben@aglogic.com.au.

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INFORMATION SHEET for Commercial PARTICIPANTS

Mrs Jo-Ann Sozou
Research Ethics Officer
Research Services
University of New England, Armidale, NSW 2351
Tel: (02) 6773 3449 Email: ethics@une.edu.au
Thank you for considering this request. I look forward to further contact with you.
To acknowledge your agreement to be involved in this study please complete the attached consent form. [redacted]

Regards, [redacted]

Emma Leonard

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CONSENT FORM for all Commercial PARTICIPANTS

/

Research Project: Overcoming the barriers to adoption of digital agriculture

I, ... have read the information contained in the Information Sheet for Commercial Participants and any questions I have asked have been answered to my satisfaction.	Yes/No
I agree to participate in this activity, realising that I may withdraw at any time.	Yes/No
I agree that research data gathered for the study may be quoted and published using a pseudonym.	Yes/No
I agree to having my interview audio recorded and transcribed.	Yes/No
I would like to receive a copy of the transcription of the interview.	Yes/No
I am older than18 years of age.	Yes/No

....
Participant Date

Email ....

Mobile phone...

....
Researcher Date

Appendix D: Surveys for Managers, Operators and Trusted Advisers

Manager

Q4a To ensure your information is linked to the correct farm business team please provide the following details. These will only be used for cross analysis purposes and all data will be de-identified when reported.

○ Name (1) ____

○ Email (2) ____

○ Name of farm business associated with research (3) ____

Q5 Approximately, what percentage of your farm business income comes from the following products? These should total 100.

_______ Cereal grain (1)
_______ Other grain crops (2)
_______ Hay/straw (3)
_______ Pasture fed beef (4)
_______ Feedlot beef (5)
_______ Pasture fed sheep (6)
_______ Feedlot sheep (7)
_______ Wool (8)
_______ Pedigree breeding stock (9)
_______ Contract farming (10)
_______ Other - please specify (11)

Q10 How many beef cattle or sheep do you run? Please provide approximate numbers for each group. If none include 0.

- ○ Breeding cows (1) ____
- ○ Young stock/replacement heifers (2) ____
- ○ Growing/finishing cattle (3) ____
- ○ Bulls (4) ____
- ○ Breeding ewes (5) ____
- ○ Young stock/replacement ewes (6) ____
- ○ Growing sheep for wool/meat (7) ____
- ○ Rams (8) ____

Q14 Do you use a third party service provider to execute any of the following tasks, and if so how often.

Select one for each.

	Never (1)	Less than once a year (2)	Annually (3)	More than once a year (4)	Monthly (5)	Weekly (6)	More than weekly (7)
Soil measurements (1)							
Crop agronomy (2)							
Business management (3)							
Animal breeding (4)							
Animal nutrition (5)							
Animal health (6)							
Processing, analysing and/or creating actions from data (7)							
Marketing (8)							
Succession planning (9)							
Machine setup and maintenance (10)							

19 How do you describe mobile phone coverage across your farm – please specify for each block as identified in Q7

	No coverage at all (1)	Less than 50% coverage (2)	50% coverage (3)	More than 50% coverage (4)	Full coverage (5)
Main farm (1)	○	○	○	○	○
Block 1 (2)	○	○	○	○	○
Block 2 (3)	○	○	○	○	○
Block 3 (4)	○	○	○	○	○
Block 4 (5)	○	○	○	○	○

Q20 Each month how much data do you buy and use in your office/home and on your mobile phone? Please report the total for combined peak and off peak allocation where relevant.

Office/home data bought (1)	▼ None (1) ... Don't know (8)
Office/home used (2)	▼ None (1) ... Don't know (8)
Mobile data bought (3)	▼ None (1) ... Don't know (8)
Mobile used (4)	▼ None (1) ... Don't know (8)

Q22 **Management, communication and guidance tools.**What technology do you use, have used or hope to use. If you use, select how often you use this technology either during the year or in a season.

	Usage				
	Don't use (1)	Use own (2)	3rd party provides (3)	Wish list (4)	Stopped using (5)
Mobile phone (1)	◯	◯	◯	◯	◯
UHF Radio (2)	◯	◯	◯	◯	◯
Digital two way radio (3)	◯	◯	◯	◯	◯
Desktop computer (4)	◯	◯	◯	◯	◯
Laptop computer (5)	◯	◯	◯	◯	◯
Touch screen device/tablet (6)	◯	◯	◯	◯	◯
Internet (7)	◯	◯	◯	◯	◯
Vehicle guidance/autosteer (8)	◯	◯	◯	◯	◯
GPS positioning (9)	◯	◯	◯	◯	◯
Robotic/autonomous equipment (10)	◯	◯	◯	◯	◯
Remotely piloted aircraft (UAV/drone) (11)	◯	◯	◯	◯	◯

Q23 Cameras, sensors and measuring toolsWhat technology do you use, have used or hope to use. If you use, select how often you use this technology either during the year or in a season.

	Usage

	Don't use (1)	Use own (2)	3rd party provides (3)	Wish list (4)	Stopped using (5)
Optical camera (1)	○	○	○	○	○
Thermal camera (13)	○	○	○	○	○
Video surveillance camera (14)	○	○	○	○	○
Automated soil surveying or sampling equipment (15)	○	○	○	○	○
Standalone environmental sensors – eg digital rain gauge, integrated weather station, soil moisture probe, frost buttons (16)	○	○	○	○	○
Connected environmental sensors – as above (17)	○	○	○	○	○
Biomass (NDVI) sensor –hand-heldd or machine mounted (18)	○	○	○	○	○
Digital pasture meter (19)	○	○	○	○	○
Reader for radio frequency ear tags (RFID) (20)	○	○	○	○	○
Automated livestock scales (21)	○	○	○	○	○
On animal technology e.g. pedometers, animal trackers or oestrus collars (22)	○	○	○	○	○

Q24 Software and data analysisWhat technology do you use, have used or hope to use. If you use, select how often you use this technology either during the year or in a season.

	Usage				
	Don't use (1)	Use own (2)	3rd party provides (3)	Wish list (4)	Stopped using (5)

Accounting software (1)					
Livestock management software (13)					
Farm management software (14)					
Precision farming software (15)					
Satellite imagery (16)					
Other remotely sensed data – digital soils maps (17)					

Q26 Which farm management software packages do you regularly use? Select or more.

- ☐ Own (1)
- ☐ AgLeader SMS (2)
- ☐ AgLeader Affinity (3)
- ☐ AgLive (4)
- ☐ AgriWeb (5)
- ☐ Agworld (6)
- ☐ Back Paddock (7)
- ☐ Case IH AFS Connect (8)
- ☐ Decipher (9)
- ☐ Fairport PAM (10)
- ☐ FarmWorks (11)
- ☐ Figured (12)
- ☐ Granular (13)
- ☐ John Deere - APEX (14)
- ☐ John Deere - Operations Centre (15)
- ☐ PCT Ag (16)
- ☐ Phoenix (17)
- ☐ Practical Systems (18)
- ☐ Production Wise (19)
- ☐ SST Software (20)
- ☐ Stock Book (21)
- ☐ Trimble Ag solutions (22)
- ☐ ⊗None (23)
- ☐ Other please specify (24)

☐ ____

Q27 Which on-line/app based decision support tools do you use? Please name as many as you like.

____

____

____

____

____

Q29 What are the main ways you currently use digital technology in your farming business? Select as many as appropriate.

☐ Communication (1)

☐ Collecting data (2)

☐ Entering and storing data (3)

☐ Sharing information (4)

☐ Analysing data (5)

☐ Creating actions from data (6)

☐ Controlling machinery (7)

☐ Remotely monitoring machinery (8)

☐ Controlling livestock (9)

☐ Remotely monitoring livestock (10)

☐ Other please specify (11) ____

Q30 How important is digital technology in managing the following activities in your business? Select not applicable if the activity does not exist eg livestock on 100% cropping or irrigation on dryland farm.

	Extremely important (1)	Very important (2)	Moderately important (3)	Slightly important (4)	Not at all important (5)	Unsure (6)	Not applicable (7)
Business administration and record keeping (1)	○	○	○	○	○	○	○
Soil surveying (2)	○	○	○	○	○	○	○
Drainage location (3)	○	○	○	○	○	○	○
Seeding (4)	○	○	○	○	○	○	○
Weed control (5)	○	○	○	○	○	○	○
Plant disease control (6)	○	○	○	○	○	○	○
Plant nutrition (7)	○	○	○	○	○	○	○
Variable rate inputs (8)	○	○	○	○	○	○	○
Irrigation (9)	○	○	○	○	○	○	○
Harvesting (10)	○	○	○	○	○	○	○
Machinery logistics (11)	○	○	○	○	○	○	○
Livestock breeding (12)	○	○	○	○	○	○	○
Livestock rationing and feeding (13)	○	○	○	○	○	○	○
Pasture allocation (14)	○	○	○	○	○	○	○
Marketing (15)	○	○	○	○	○	○	○
Other please specify (16)	○	○	○	○	○	○	○

Q31 What type of decisions are you or your employees making using data gathered by digital technology?

	Manager (1)	Employee (2)
Simple decisions - single variable - eg using a moisture probe to signal need for irrigation to be switched on or off. (1)	☐	☐
Complicated decisions - multiple variables - eg using soil and weather data to create a variable rate irrigation application rate (2)	☐	☐
Neither (3)	☐	☐

Q35 Which statements most closely represent why you use digital technology in your business? Select one or more.

☐ I like digital technology so I use it wherever possible in the business. (1)

☐ Digital technology improves the efficiency of my business. (2)

☐ I need to use digital technology in order to keep up with others in my industry. (3)

☐ I use digital technology because it gives me peace of mind when away from the farm. (4)

☐ Using digital technology will encourage the next generation to be involved with our farm. (5)

☐ I use digital technology because it improves productivity. (6)

☐ Using digital technology will help attract better employees. (7)

☐ Digital technology provides traceability along the value chain which my customers demand. (8)

☐ None of the above – please explain why you use. (9) ____

Q36 Which statements most closely represent your attitude to using digital technology? Select

Yes, No, or Not sure for each statement.

	Yes (1)	No (2)	Not sure (3)
I like to try new digital technology as soon as it's available. (1)	○	○	○
I wait until digital technology has been proved to be useful by others. (2)	○	○	○
I tend to use digital technologies only when there is a need identified by others (3)	○	○	○
I am keen to adopt new technology when it solves a specific problem (4)	○	○	○
I avoid using digital technology (5)	○	○	○
Overall digital technology helps my business but it can waste a lot of my time. (6)	○	○	○
I only use digital technology that is easy to install and learn. (7)	○	○	○

Q37 When trying to master a form of digital agricultural technology which of the following do you use and how useful are they for you?

	Extremely useful (1)	Moderately useful (2)	Slightly useful (3)	Neither useful nor useless (4)	Slightly useless (5)	Moderately useless (6)	Extremely useless (7)	Don't use (8)
Online forums (1)	o	o	o	o	o	o	o	o
Online video guides (2)	o	o	o	o	o	o	o	o
My own knowledge and experience (3)	o	o	o	o	o	o	o	o
Knowledge and experience of a family member or employee (4)	o	o	o	o	o	o	o	o
Knowledge and experience of another farmer (5)	o	o	o	o	o	o	o	o
Specialist in digital agriculture (6)	o	o	o	o	o	o	o	o
Product technical support from a local dealer (7)	o	o	o	o	o	o	o	o
Product technical support remote/online (8)	o	o	o	o	o	o	o	o

Q41 If you answered No to Q38 please select all of the reasons for not having an annual budget for technology? Select one or more.

- ☐ (1) Digital technology is included in other budget lines eg office equipment, capital items
- ☐ The digital technology is included with the price of machinery. (2)
- ☐ We never buy digital technology. (3)
- ☐ Purchases of digital technology are infrequent. (4)
- ☐ A separate budget line for digital technology has not been considered. (5)
- ☐ Digital technology is a luxury and only purchased when we have surplus funds. (6)
- ☐ Other – please explain (7) ____

Q43 Digital technologies offer different benefits (value propositions). What return on investment, over a three year period, would be required for you to invest in digital technology that provide the following value propositions? Select one for each value proposition.

	Nil (1)	Less than 1% (2)	1 % to 3% (3)	3.1% to 5% (4)	5.1% to 7% (5)	7.1% to 10% (6)	Unsure (7)
Increased output/reduced inputs (1)	○	○	○	○	○	○	○
Time saving (2)	○	○	○	○	○	○	○
Improved health and safety eg reduced fatigue (3)	○	○	○	○	○	○	○
Improved security (4)	○	○	○	○	○	○	○
Improved peace of mind (5)	○	○	○	○	○	○	○

Q45 What are the factors that you feel are holding you back from further investment in digital agriculture technology? Share as few or many factors as you like.

____

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Q46 How do the following factors influence you when considering purchasing new digital technology? Rank each of the following influences from a very strong influence to no influence at all.

	Very strong influence (1)	Strong influence (2)	Neither strong or weak influence (3)	Weak influence (4)	No influence at all (5)
Cross machine or platform compatibility (1)	○	○	○	○	○
Good local backup (2)	○	○	○	○	○
Ease of use (3)	○	○	○	○	○
Training included in the purchase (4)	○	○	○	○	○
A clearly demonstrated return on investment/value proposition (5)	○	○	○	○	○
Recommendation from a user you know (6)	○	○	○	○	○
Recommendation from a user you don't know via media/social media/ presentation etc (7)	○	○	○	○	○
Your gut feeling is this will be a good investment (8)	○	○	○	○	○
Enthusiasm for a digital technology from a member of your business (9)	○	○	○	○	○
Product reviews (10)	○	○	○	○	○

Q47 How do you feel about the following statements? Select how strongly you agree or disagree.

	Strongly agree (1)	Agree (2)	Somewhat agree (3)	Neither agree nor disagree (4)	Somewhat disagree (5)	Disagree (6)	Strongly disagree (7)
Digital technology enables more in depth information to be gathered. (1)	○	○	○	○	○	○	○
Digital technology enables information to be analysed more easily. (2)	○	○	○	○	○	○	○
The digital technology I have used is not sufficiently developed to meet my needs. (3)	○	○	○	○	○	○	○
Digital technology helps make my business more profitable. (4)	○	○	○	○	○	○	○
Digital technology makes my business more reliant on external parties to keep it operating. (5)	○	○	○	○	○	○	○
The systems required to analyse, interpret and create actions from agricultural data are currently lacking. (6)	○	○	○	○	○	○	○
I regularly update our digital technology as I like to keep up to date. (7)	○	○	○	○	○	○	○
I avoid updating digital technology because learning new systems takes time. (8)	○	○	○	○	○	○	○
Before I buy new digital technology I have to be able to establish a cost benefit for my business. (9)	○	○	○	○	○	○	○
Buying digital technology is confusing because there are so many options. (10)	○	○	○	○	○	○	○
Lack of connectivity is the biggest barrier to using digital technology in my business (11)	○	○	○	○	○	○	○
Buying digital technology is hard to justify because there are few clearly demonstrated value propositions. (12)	○	○	○	○	○	○	○
I only want to input data once not every time I use a different software package. (13)	○	○	○	○	○	○	○
There is a lack of support to make digital technologies work on-farm. (14)	○	○	○	○	○	○	○
With more training I would use more digital technology. (15)	○	○	○	○	○	○	○

Q55 How is your work time divided? Provide an approximate percentage for each. The total

should be 100%.
_______ Strategic farm management (1)
_______ Operational management (2)
_______ Hands-on operational (3)
_______ Administration (4)
_______ Paid off farm employment (5)

Operations

Q4a To ensure your information is linked to the correct farm business team please provide the following details. These will only be used for cross analysis purposes and all data will be de-identified when reported.

○ Name (1) ____

○ Email (2) ____

○ Name of farm business associated with research (3) ____

Q7 Approximately, what percentage of your time is spent working in the following areas? These should total 100.
_______ Grain production (1)
_______ Working with beef cattle (2)
_______ Working with sheep (3)
_______ Transport - truck driving (4)
_______ Working on irrigation (5)
_______ Machinery, equipment - building, modifications, repairs and maintenance (6)
_______ Other please specify (7)

Q10 How do you like to receive instructions from your boss? Select a preference for each statement.

	Like a great deal (1)	Like a moderate amount (2)	Like a little (3)	Neither like nor dislike (4)	Dislike a little (5)	Dislike a moderate amount (6)	Dislike a great deal (7)
Verbally - face to face (1)	○	○	○	○	○	○	○
Verbally by phone (2)	○	○	○	○	○	○	○
Verbally as a voice message (3)	○	○	○	○	○	○	○
Written on a white board/notice board (4)	○	○	○	○	○	○	○
Written as a worksheet or in a book - hard copy (5)	○	○	○	○	○	○	○
Written as text messages (6)	○	○	○	○	○	○	○
Written and received as an e-mail (7)	○	○	○	○	○	○	○
Written in a digital app/program which I access using my computer, smart phone or tablet (8)	○	○	○	○	○	○	○

Q11 How do you like to report actions and observations back to your boss? Select a preference for each statement.

	Like a great deal (1)	Like a moderate amount (2)	Like a little (3)	Neither like nor dislike (4)	Dislike a little (5)	Dislike a moderate amount (6)	Dislike a great deal (7)
Verbally - face to face (1)	○	○	○	○	○	○	○
Verbally by phone (2)	○	○	○	○	○	○	○
Verbally as a voice message (3)	○	○	○	○	○	○	○
Written on a white board/notice board (4)	○	○	○	○	○	○	○
Written as a worksheet or in a book - hard copy (5)	○	○	○	○	○	○	○
Written as text messages (6)	○	○	○	○	○	○	○
Written and received as an e-mail (7)	○	○	○	○	○	○	○
Written in a digital app/program which I access using my computer, smart phone or tablet (8)	○	○	○	○	○	○	○

Q18 **Management, communication and guidance tools.** What technology do you use, have used or hope to use. If you use, select how often you use this technology either during the year or in a season.

	Usage				
	Don't use (1)	Don't have	Use (3)	Wish list (4)	Stopped using (5)

		(2)			
Mobile phone (1)	◯	◯	◯	◯	◯
UHF Radio (2)	◯	◯	◯	◯	◯
Digital two way radio (3)	◯	◯	◯	◯	◯
Desktop computer (4)	◯	◯	◯	◯	◯
Laptop computer (5)	◯	◯	◯	◯	◯
Touch screen device/tablet (6)	◯	◯	◯	◯	◯
Internet (7)	◯	◯	◯	◯	◯
Vehicle guidance/autosteer (8)	◯	◯	◯	◯	◯
GPS positioning (9)	◯	◯	◯	◯	◯
Robotic/autonomous equipment (10)	◯	◯	◯	◯	◯
Remotely piloted aircraft (UAV/drone) (11)	◯	◯	◯	◯	◯

Q19 Cameras, sensors and measuring toolsWhat technology do you use, have used or hope to use. If you use, select how often you use this technology either during the year or in a season.

	Usage				
	Don't use (1)	Don't use (2)	Use (3)	Wish list (4)	Stopped using (5)
Optical camera (1)	○	○	○	○	○
Thermal camera (13)	○	○	○	○	○
Video surveillance camera (14)	○	○	○	○	○
Automated soil surveying or sampling equipment (15)	○	○	○	○	○
Standalone environmental sensors – eg digital rain gauge, integrated weather station, soil moisture probe, frost buttons (16)	○	○	○	○	○
Connected environmental sensors – as above (17)	○	○	○	○	○
Biomass (NDVI) sensor –hand-heldd or machine mounted (18)	○	○	○	○	○
Digital pasture meter (19)	○	○	○	○	○
Reader for radio frequency ear tags (RFID) (20)	○	○	○	○	○
Automated livestock scales (21)	○	○	○	○	○
On animal technology e.g. pedometers, animal trackers or oestrus collars (22)	○	○	○	○	○

Q20 Software and data analysisWhat technology do you use, have used or hope to use. If you use, select how often you use this technology either during the year or in a season.

	Usage				
	Don't use (1)	Don't have (2)	Use (3)	Wish list (4)	Stopped using (5)

Accounting software (1)	○	○	○	○	○
Livestock management software (13)	○	○	○	○	○
Farm management software (14)	○	○	○	○	○
Precision farming software (15)	○	○	○	○	○
Satellite imagery (16)	○	○	○	○	○
Other remotely sensed data – digital soils maps (17)	○	○	○	○	○

Q21 Which farm management software packages do you regularly use? Select one or more.

- ▢ Own (1)
- ▢ AgLeader SMS (2)
- ▢ AgLeader Affinity (3)
- ▢ AgLive (4)
- ▢ AgriWeb (5)
- ▢ Agworld (6)
- ▢ Back Paddock (7)
- ▢ Case IH AFS Connect (8)
- ▢ Decipher (9)
- ▢ Fairport PAM (10)
- ▢ FarmWorks (11)
- ▢ Figured (12)
- ▢ Granular (13)
- ▢ John Deere - APEX (14)
- ▢ John Deere - Operations Centre (15)
- ▢ PCT Ag (16)
- ▢ Phoenix (17)
- ▢ Practical Systems (18)
- ▢ Production Wise (19)
- ▢ SST Software (20)
- ▢ Stock Book (21)
- ▢ Trimble Ag solutions (22)
- ▢ None (23)
- ▢ Other please specify (24) ____

Q22 Which on-line/app based decision support tools do you use? Please name as many as you like.

____

____

____

____

____

Q24 What are the main ways you currently use digital technology in your farm work? Select as many as appropriate.

- ☐ Communication (1)
- ☐ Collecting data eg weather station, moisture probe (2)
- ☐ Entering and storing data (3)
- ☐ Sharing information (4)
- ☐ Analysing data (5)
- ☐ Creating actions from data (6)
- ☐ Controlling machinery eg autosteer (7)
- ☐ Remotely monitoring machinery (8)
- ☐ Controlling livestock (9)
- ☐ Remotely monitoring livestock (10)
- ☐ Other please specify (11) ____

Q25 Which statements most closely represent why you use digital technology in your farm work? Select one or more.

- ☐ I dislike digital technology and don’t use it (1)
- ☐ I dislike digital technology but use it a little (2)
- ☐ I dislike digital technology but use it a lot (3)
- ☐ I don’t feel strongly either way about digital technology and use when requested (4)
- ☐ I like digital technology but lack the knowledge to make it work (5)
- ☐ I like digital technology but lack confidence to learn new systems (6)
- ☐ I like digital technology and try to learn how to use multiple functions (7)
- ☐ I am a digital technology junkie and will use technology wherever possible (8)

Q26 When presented with a digital technology that you have not used before, how do you learn how it works? Select Yes, No, or Maybe for each statement)

	Yes (1)	No (2)	Maybe (3)
I teach myself by trial and error (1)	○	○	○
I read the instructions or use on-line forums, tutorials (2)	○	○	○
I ask someone younger to show me (3)	○	○	○
I ask my partner/colleagues/friends to teach me (4)	○	○	○
I want to learn but don't know where to find information (5)	○	○	○
I don't learn how to use it and only use it if someone else has set it up for me. (6)	○	○	○
I call the software/hardware support specialist (7)	○	○	○

Service provider

Q10 What are the main types of services that the business you work for provides to farming clients and which are the main services you personally provide to clients? Tick 1 or more. Select one for each.

	Services provided by the business (1)	Services provided by you to any client (2)
Soil measurements (1)	☐	☐
Crop agronomy (2)	☐	☐
Business management (3)	☐	☐
Animal breeding (4)	☐	☐
Animal nutrition (5)	☐	☐
Animal health (6)	☐	☐
Processing, analysing and/or creating actions from data (7)	☐	☐
Marketing (8)	☐	☐
Succession planning (9)	☐	☐
Machine setup and maintenance (10)	☐	☐
Accounting (11)	☐	☐
Business investment planning (12)	☐	☐

Q12 **Management, communication and guidance tools.**What technology do you use, have used or hope to use. If you use, select how often you use this technology either during the year or in a season.

	Usage				
	Don't use (1)	Own (2)	Clients (3)	Wish list (4)	Stopped using (5)
Mobile phone (1)	○	○	○	○	○
UHF Radio (2)	○	○	○	○	○
Digital two way radio (3)	○	○	○	○	○
Desktop computer (4)	○	○	○	○	○
Laptop computer (5)	○	○	○	○	○
Touch screen device/tablet (6)	○	○	○	○	○
Internet (7)	○	○	○	○	○
Vehicle guidance/autosteer (8)	○	○	○	○	○
GPS positioning (9)	○	○	○	○	○
Robotic/autonomous equipment (10)	○	○	○	○	○
Remotely piloted aircraft (UAV/drone) (11)	○	○	○	○	○

Q13 Cameras, sensors and measuring toolsWhat technology do you use, have used or hope to use. If you use, select how often you use this technology either during the year or in a season.

	Usage				
	Don't use (1)	Own (2)	Clients (3)	Wish list (4)	Stopped using (5)
Optical camera (1)	○	○	○	○	○
Thermal camera (13)	○	○	○	○	○
Video surveillance camera (14)	○	○	○	○	○
Automated soil surveying or sampling equipment (15)	○	○	○	○	○
Standalone environmental sensors – eg digital rain gauge, integrated weather station, soil moisture probe, frost buttons (16)	○	○	○	○	○
Connected environmental sensors – as above (17)	○	○	○	○	○
Biomass (NDVI) sensor –hand-heldd or machine mounted (18)	○	○	○	○	○
Digital pasture meter (19)	○	○	○	○	○
Reader for radio frequency ear tags (RFID) (20)	○	○	○	○	○
Automated livestock scales (21)	○	○	○	○	○
On animal technology e.g. pedometers, animal trackers or oestrus collars (22)	○	○	○	○	○

Q14 Software and data analysisWhat technology do you use, have used or hope to use. If you use, select how often you use this technology either during the year or in a season.

	Usage

	Don't use (1)	Own (2)	Clients (3)	Wish list (4)	Stopped using (5)
Accounting software (1)	○	○	○	○	○
Livestock management software (13)	○	○	○	○	○
Farm management software (14)	○	○	○	○	○
Precision farming software (15)	○	○	○	○	○
Satellite imagery (16)	○	○	○	○	○
Other remotely sensed data – digital soils maps (17)	○	○	○	○	○

Q16 Which farm management software packages do you use to provide services to your farming clients? Select or more.

- ☐ Own (1)
- ☐ AgLeader SMS (2)
- ☐ AgLeader Affinity (3)
- ☐ AgLive (4)
- ☐ AgriWeb (5)
- ☐ Agworld (6)
- ☐ Back Paddock (7)
- ☐ Case IH AFS Connect (8)
- ☐ Decipher (9)
- ☐ Fairport PAM (10)
- ☐ FarmWorks (11)
- ☐ Figured (12)
- ☐ Granular (13)
- ☐ John Deere - APEX (14)
- ☐ John Deere - Operations Centre (15)
- ☐ PCT Ag (16)
- ☐ Phoenix (17)
- ☐ Practical Systems (18)
- ☐ Production Wise (19)
- ☐ SST Software (20)
- ☐ Stock Book (21)
- ☐ Trimble Ag solutions (22)
- ☐ ⊗None (23)
- ☐ Other please specify (24) ____

Q19 What are the main ways you currently use digital technology when working with farming clients? Select as many as appropriate.

- ☐ Communication (1)
- ☐ Collecting data (2)
- ☐ Entering and storing data (3)
- ☐ Sharing information (4)
- ☐ Analysing data (5)
- ☐ Creating actions from data (6)
- ☐ Controlling machinery (7)
- ☐ Remotely monitoring machinery (8)
- ☐ Controlling livestock (9)
- ☐ Remotely monitoring livestock (10)
- ☐ Other please specify (11) ____

Q21 How important do you think digital technology is for your nominating client when they are managing the following activities? Select not applicable if the activity does not exist eg livestock on 100% cropping or irrigation on dryland farm.

	Extremely important (1)	Very important (2)	Moderately important (3)	Slightly important (4)	Not at all important (5)	Unsure (6)	Not applicable (7)
Business administration and record keeping (1)	◯	◯	◯	◯	◯	◯	◯
Soil surveying (2)	◯	◯	◯	◯	◯	◯	◯
Drainage location (3)	◯	◯	◯	◯	◯	◯	◯
Seeding (4)	◯	◯	◯	◯	◯	◯	◯
Weed control (5)	◯	◯	◯	◯	◯	◯	◯
Plant disease control (6)	◯	◯	◯	◯	◯	◯	◯
Plant nutrition (7)	◯	◯	◯	◯	◯	◯	◯
Variable rate inputs (8)	◯	◯	◯	◯	◯	◯	◯
Irrigation (9)	◯	◯	◯	◯	◯	◯	◯
Harvesting (10)	◯	◯	◯	◯	◯	◯	◯
Machinery logistics (11)	◯	◯	◯	◯	◯	◯	◯
Livestock breeding (12)	◯	◯	◯	◯	◯	◯	◯
Livestock rationing and feeding (13)	◯	◯	◯	◯	◯	◯	◯
Pasture allocation (14)	◯	◯	◯	◯	◯	◯	◯
Marketing (15)	◯	◯	◯	◯	◯	◯	◯
Other - please specify (16)	◯	◯	◯	◯	◯	◯	◯

Q24 Do you have remote access to your nominating clients data, machine settings or sensors via a cloud service? Select if you have access.

	All (1)	Some (2)	None (3)
Remote access to data (1)	○	○	○
Remote access to machine settings (2)	○	○	○
Remote access to sensors (3)	○	○	○

Q32 Each month how much data do you buy and use in your office/home and on your mobile phone? Please report the total for combined peak and off peak allocation where relevant.

Office/home data bought (1)	▼ None (1) ... Don't know (8)
Office/home used (2)	▼ None (1) ... Don't know (8)
Mobile data bought (3)	▼ None (1) ... Don't know (8)
Mobile used (4)	▼ None (1) ... Don't know (8)

Q35 Which statements most closely represent why you use digital technology in your business? Select one or more.

- ▢ I like digital technology so I use it wherever possible in the business. (1)
- ▢ Digital technology improves the efficiency of my business. (2)
- ▢ I need to use digital technology in order to keep up with others in my industry. (3)
- ▢ I use digital technology because it gives me peace of mind when away from the farm. (4)
- ▢ Using digital technology will encourage the next generation to be involved with our farm. (5)
- ▢ I use digital technology because it improves productivity. (6)
- ▢ Using digital technology will help attract better employees. (7)
- ▢ Digital technology provides traceability along the value chain which my customers demand. (8)
- ▢ None of the above – please explain why you use. (9) ____

Q36 Which statements most closely represent your attitude to using digital technology? Select Yes, No, or

Not sure for each statement.

	Yes (1)	No (2)	Not sure (3)
I like to try new digital technology as soon as it's available. (1)	○	○	○
I wait until digital technology has been proved to be useful by others. (2)	○	○	○
I tend to use digital technologies only when there is a need identified by others (3)	○	○	○
I am keen to adopt new technology when it solves a specific problem (4)	○	○	○
I avoid using digital technology (5)	○	○	○
Overall digital technology helps my business but it can waste a lot of my time. (6)	○	○	○
I only use digital technology that is easy to install and learn. (7)	○	○	○

Q37 When trying to master a form of digital agricultural technology in your business which of the following do you use and how useful are they for you?

	Extremely useful (1)	Moderately useful (2)	Slightly useful (3)	Neither useful nor useless (4)	Slightly useless (5)	Moderately useless (6)	Extremely useless (7)	Don't use (8)
Online forums (1)	○	○	○	○	○	○	○	○
Online video guides (2)	○	○	○	○	○	○	○	○
My own knowledge and experience (3)	○	○	○	○	○	○	○	○
Knowledge and experience of a family member or employee (4)	○	○	○	○	○	○	○	○
Knowledge and experience of another farmer (5)	○	○	○	○	○	○	○	○
Specialist in digital agriculture (6)	○	○	○	○	○	○	○	○
Product technical support from a local dealer (7)	○	○	○	○	○	○	○	○
Product technical support remote/online (8)	○	○	○	○	○	○	○	○

Q42 How do the following factors influence you when considering purchasing new digital technology?

Rank each of the following influences from a very strong influence to no influence at all.

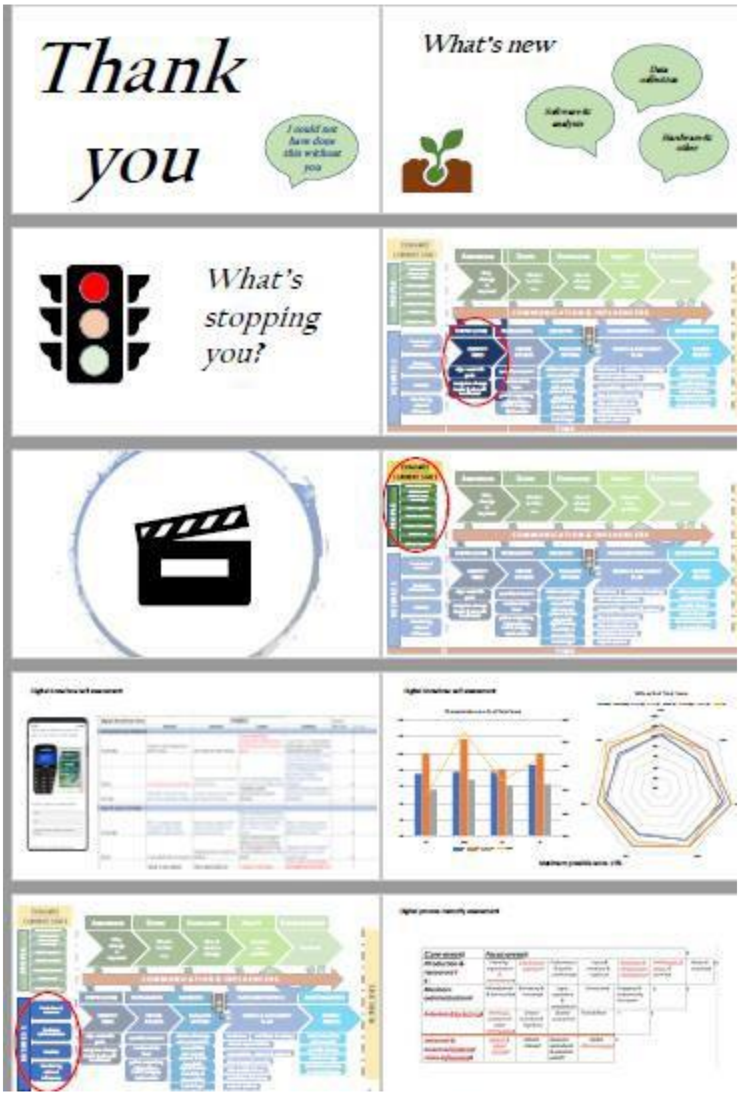
	Very strong influence (1)	Strong influence (2)	Neither strong or weak influence (3)	Weak influence (4)	No influence at all (5)
Cross machine or platform compatibility (1)	○	○	○	○	○
Good local backup (2)	○	○	○	○	○
Ease of use (3)	○	○	○	○	○
Training included in the purchase (4)	○	○	○	○	○
A clearly demonstrated return on investment/value proposition (5)	○	○	○	○	○
Recommendation from a user you know (6)	○	○	○	○	○
Recommendation from a user you don't know via media/social media/ presentation etc (7)	○	○	○	○	○
Your gut feeling is this will be a good investment (8)	○	○	○	○	○
Enthusiasm for a digital technology from a member of your business (9)	○	○	○	○	○
Product reviews (10)	○	○	○	○	○

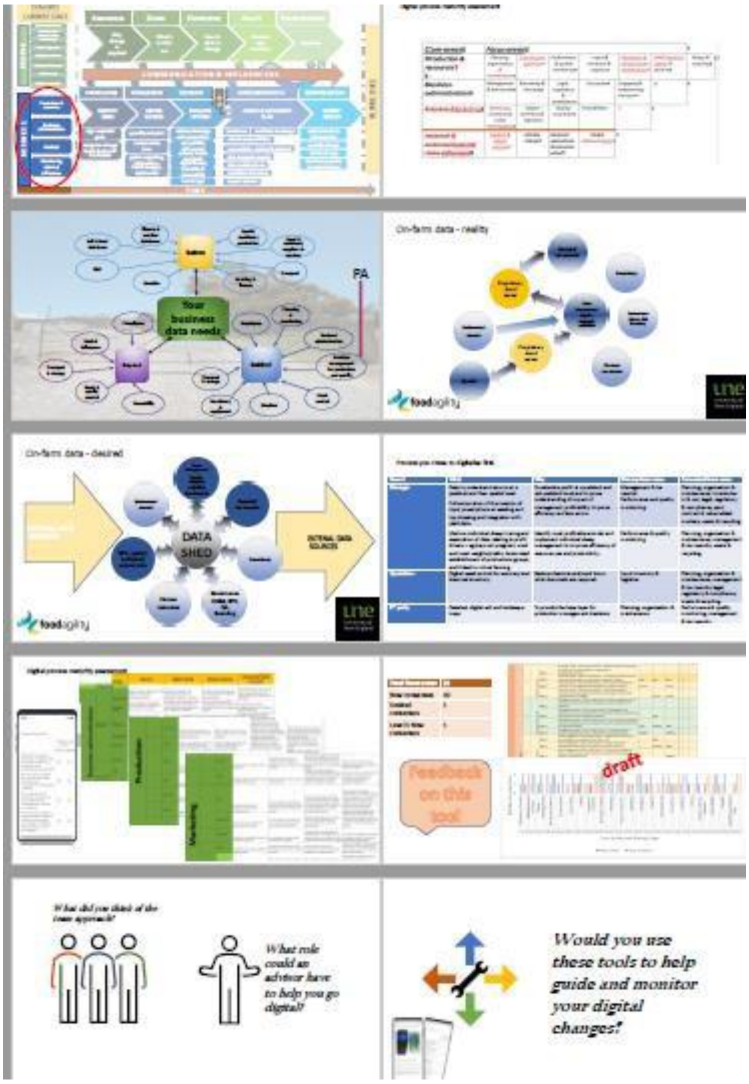
Q43 How do you feel about the following statements? Select how strongly you agree or disagree.

	Strongly agree (1)	Agree (2)	Somewhat agree (3)	Neither agree nor disagree (4)	Somewhat disagree (5)	Disagree (6)	Strongly disagree (7)
Digital technology enables more in depth information to be gathered. (1)	○	○	○	○	○	○	○
Digital technology enables information to be analysed more easily. (2)	○	○	○	○	○	○	○
The digital technology I have used is not sufficiently developed to meet my needs. (3)	○	○	○	○	○	○	○
Digital technology helps make my business more profitable. (4)	○	○	○	○	○	○	○
Digital technology makes my business more reliant on external parties to keep it operating. (5)	○	○	○	○	○	○	○
The systems required to analyse, interpret and create actions from agricultural data are currently lacking. (6)	○	○	○	○	○	○	○
I regularly update my digital technology as I like to keep up to date. (7)	○	○	○	○	○	○	○
I avoid updating digital technology because learning new systems takes time. (8)	○	○	○	○	○	○	○
Before I buy new digital technology I have to be able to establish a cost benefit for my business. (9)	○	○	○	○	○	○	○

Buying digital technology is confusing because there are so many options. (10)							
Lack of connectivity is the biggest barrier to using digital technology in my business (11)							
Buying digital technology is hard to justify because there are few clearly demonstrated value propositions. (12)							
I only want to input data once not every time I use a different software package. (13)							
There is a lack of support to make digital technologies work on-farm. (14)							
With more training I would use more digital technology. (15)							

Appendix E: Exit Survey Feedback Presentation




Your business data needs
FA
On-farm data - reality
On-farm data - desired
DATA SHED
Production
Marketing
Feedback on this tool
draft
What did you think of the team approach?
What role could an advisor have to help you go digital?
Would you use these tools to help guide and monitor your digital changes?

Appendix F: Digital Knowhow Self-assessment

Numbers in brackets represent code not score.

Digital Knowhow Self-Assessment

Start of Block: Default Question Block

Q1
Based on your feedback and the need to validate the results, please find what I am hoping will be the final draft of the Digital KnowHow Self-Assessment Tool. Grab a cuppa, record your start time and go - again it will be quick.
I will collate your answers to provide your digital knowhow result and what this means. All data is made anonymous and will only be shared within your farming business team.

Q2 What type of phone do you use? click on the name on the image

Q3 I use my phone to make calls

- YES (1)
- NO (2)
- I don't have a mobile or smart phone (3)

Q4 Select the number that most closely relates to your agreement or disagreement with the statement about digital communication

	Strongly disagree 0 1 2 3 4 5 6 7 8 9 10 Strongly agree
I like that my phone allows me to be in constant contact ()	
As new functions are added I learn how to use them ()	
I consider mobile communication vital for farming ()	
I seek out ways to overcome connectivity issues/reception blackspots ()	

Q5 GPS is a satellite-based navigation system that provides location details

- True (1)
- False (2)
- Not sure (3)

Q6 I can attach files to an email

- YES (1)
- NO (2)

Q7 I can recognise the diary icon on my phone

- YES (1)
- NO (2)

Q8 I record notes on a mobile device

- Always (1)
- Most of the time (2)
- About half the time (3)
- Sometimes (4)
- Never (5)

Q9 My previous searches on the internet influence the results of subsequent searches

- True (1)
- False (2)
- Not sure (3)

Q10 I use a web browser search engine to find websites

- YES (1)
- NO (2)
- Not sure (3)

Q11 Select your level of agreement with the following statements about selecting and setting up digital technology

	Strongly disagree										Strongly agree
	0	1	2	3	4	5	6	7	8	9	10
I prefer to use an online help desk than refer to a book or manual ()											
I like to personalise my phone and/or computer settings and displays ()											
I am happy spending time learning how to use a new digital technology ()											
When presented with a new digital technology I try to use it immediately ()											

Q12 When printed or presented on screen, which direction is normally at the top of the page?

- ○ North (1)
- ○ South (2)
- ○ East (3)
- ○ West (4)

Q13 I can read data from a display/screen and relate it to a remembered value - e.g. electric fence tester, coverage map

- ○ YES (1)
- ○ NO (2)

Q14 I have heard of variable rate inputs

◯ YES (1)

◯ NO (2)

Q15 I can use online/internet banking

◯ YES (1)

◯ NO (2)

Q16 I understand that not all information on the internet is reliable and some email attachments can damage my files if opened

◯ YES (1)

◯ NO (2)

◯ Not sure (3)

Q17 I can setup and use a pass code/password

◯ YES (1)

◯ NO (2)

Q18 How do you feel about the following statements about digital approaches to planning and organising?

	Strongly disagree										Strongly agree
	0	1	2	3	4	5	6	7	8	9	10

Farming is easier with digital tools to collect data ()	
With more information and data I can do a better job ()	
Collecting information in a digital format makes planning easier ()	
I like to use multiple sources of information/data to makes plans/projections ()	

Q19 I am aware of video calling

- YES (1)
- NO (2)

Q20 I use my phone to make calls and send texts

- YES (1)
- NO (2)

Q21 Identify which types of GPS require a base station as a source of correction

- Mobile phone (1)
- DGPS (2)
- RTK (3)
- Not sure (4)

Q22 Weather is an important variable for farming - select the main way that you access weather data.

- ○ Local radio or TV forecasts (1)
- ○ Weather app on my phone (2)
- ○ Weather app and on-farm weather station data (3)
- ○ Weather app plus data from a network of IOT weather stations (4)

Q23 I know data can be stored on the cloud

- ○ YES (1)
- ○ NO (2)
- ○ Not sure (3)

Q24 I use a digital diary or notes on phone

- ○ YES (1)
- ○ NO (2)

Q25 How strongly do you feel about these questions that relate to gathering data?

	Strongly disagree										Strongly agree
	0	1	2	3	4	5	6	7	8	9	10

I find search engines easy to use ()	
I think connected (IOT) sensors can help collect data across large areas ()	
I like to use my digital photos and 'how to videos ' from the internet to help with problems or task ()	
I think data should be collected even if there is no current use ()	

Q26 Google, Bing, and Safari are all examples of search engines

- True (1)
- False (2)
- Not sure (3)

Q27 I record observations as photos and videos

- YES (1)
- NO (2)

Q28 When digital maps are rotated north will remain at the top of the screen

- True (1)
- False (2)
- Not sure (3)

Q29 I can physically go to a location that is marked on a digital map

◯ YES (1)

◯ NO (2)

Q30 Select the use for each technology

	Location (1)	Connectivity (2)	Data storage (3)	Don't know/none (4)
Satellite (1)	◯	◯	◯	◯
Virtual fencing (2)	◯	◯	◯	◯
Server (3)	◯	◯	◯	◯
Bluetooth (4)	◯	◯	◯	◯
RTK (5)	◯	◯	◯	◯
RFID (6)	◯	◯	◯	◯
Wi-Fi (7)	◯	◯	◯	◯
Cloud (8)	◯	◯	◯	◯
GPS (9)	◯	◯	◯	◯
USB stick (10)	◯	◯	◯	◯
A-B line (11)	◯	◯	◯	◯
Hard drive (12)	◯	◯	◯	◯

Q31 To automatically identify my location on a live digital map, location settings must be on

- True (1)
- False (2)
- Not sure (3)

Q32 I can only use basic digital tools and data sources after they are set up by someone else

- YES (1)
- NO (2)

Q33 I know that software updates are important to maintain device security

- YES (1)
- NO (2)
- Not sure (3)

Q34 I update antivirus and other software manually

- YES (1)
- NO (2)
- Not sure (3)

Q35 I have heard about collaborative software tools for business such as Teams or Slack

◯ YES (1)

◯ NO (2)

Q36 I use a voice activated smart assistant on my mobile phone

◯ YES (1)

◯ NO (2)

◯ Not sure (3)

Q37 Select the approximate level of accuracy of for each of the GPS systems

	Approximate accuracy				
	+/- 5m (1)	+/- 1-2m (2)	+/- 10-20cm (3)	+/- 2.5cm (4)	Don't know (5)
Mobile phone (1)	◯	◯	◯	◯	◯
DGPS (2)	◯	◯	◯	◯	◯
RTK (3)	◯	◯	◯	◯	◯

Q38 I setup and use a range of digital on-farm technology e.g. GPS guidance, A-B lines or auto-drafting rules, or fly a drone.

◯ YES (1)

◯ NO (2)

Q39 A logical filing system makes data storage and retrieval faster

- ○ True (1)
- ○ False (2)
- ○ Not sure (3)

Q40 I use cloud based storage solutions (e.g. Google Drive, Dropbox, iCloud, JD Office) to access files across devices

- ○ YES (1)
- ○ NO (2)

Q41 How strongly do you feel about these questions that relate to analysing and interpreting data?

	Strongly disagree ... Strongly agree 0 1 2 3 4 5 6 7 8 9 10
Recording data in software/apps, rather than on paper helps when reviewing historic records ()	
I am happy to renter the same data into different software ()	
I seek out software and methods to improve data interpretation and analysis ()	
I am keen to use artificial intelligence (AI) to analysing patterns in data ()	

Q42 Data entered into some apps cannot be transferred to another app.

- True (1)
- False (2)
- Not sure (3)

Q43 I can setup spreadsheets to store data such as rainfall, liveweight etc

- YES (1)
- NO (2)

Q44 I can easily find benchmarks and target values against which to analyse data, e.g. water use efficiency, growth rate, return on investment

- YES (1)
- YES but not easily (2)
- NO (3)
- Not sure (4)

Q45 I can use a spatial map to plan a management action , e.g. vary lime rates based on pH, move stock or adjust fertiliser rates to biomass

- YES (1)
- NO (2)

Q46 I know systems exist to automate data management

- YES (1)
- NO (2)

Q47 I can setup and/or calibrate digital tools such as a yield monitor, rate controller or digital scales

- YES (1)
- NO (2)

Q48 How strongly do you feel about these questions that relate to decisions or actions supported by digital data?

	Strongly disagree 0 1 2 3 4 5 6 7 8 9 10 Strongly agree
Digital data makes decisions making easier ()	
Using device location settings can improve on-farm logistics, increase safety and efficiency ()	
Using digital tools and approaches increases productivity ()	
I am excited about the use of robotic technology on farm ()	

Q49 I am always alert for spam emails, attachments and texts

- YES (1)
- NO (2)

Q50 How often do you back-up your data?

- Never (1)
- Sometimes (2)
- Daily - manual (3)
- Back-ups are automated and go to a hard drive (4)
- Back-ups are automated and go to a cloud server (5)

Q51 How strongly do you feel about these questions that relate to data security and online safety?

	Strongly disagree ... Strongly agree 0 1 2 3 4 5 6 7 8 9 10
I am happy to use my credit card for online transactions ()	
I think updating software is a quick and easy job ()	
In our business, data security is a high priority ()	
I regularly review and improve data security processes. ()	

Q52 Augmented or virtual reality technologies can be built into induction/training tools

- True (1)
- False (2)
- Not sure (3)

Q53 I use a collaboration software e.g. Teams or Slack to communicate with work colleagues

- ◯ YES (1)
- ◯ NO (2)
- ◯ Not sure (3)

Q54 If there is a problem with digital technology do you? Select one.

- ◯ Leave it for someone else to fix (1)
- ◯ Ask a colleague to help fix it (2)
- ◯ Contact the dealer or online support to help sort the problem (3)
- ◯ Use your experience and knowledge and work with specialists when required (4)

Q55 SBAS is a satellite correction system that would improve GPS accuracy to 1cm

- ◯ True (1)
- ◯ False (2)
- ◯ Not sure (3)

Q56 I program rules to customise farming software to meet specific needs

- ◯ YES (1)
- ◯ NO (2)

Q57 An in-house, dedicate server for data storage gives you greater control over your data, than cloud storage

- True (1)
- False (2)
- Not sure (3)

Q58 I have set-up systems so files can easily be found and retrieved remotely by other members of the team

- YES (1)
- NO (2)

Q59 A dashboard is a tool to present multiple sources of data

- True (1)
- False (2)
- Not sure (3)

Q60 I combine and analyse data from different digital sources to support more decisions

- YES (1)
- NO (2)

Q61 I work with specialists to create processes to analyse data to meet specific needs

- YES (1)
- NO (2)

Q62 I use artificial intelligence (AI) to analyse and interpret data sets

- YES (1)
- NO (2)
- Not sure (3)

Q63 I seek out peers and researchers using and developing technologies that might be relevant to agriculture

- YES (1)
- NO (2)

Q64 I setup automated routines to initiate actions from data, often from multiple data set

- YES (1)
- NO (2)

Q65 I use online forums to stay abreast of new digital security threats

- YES (1)
- NO (2)

Q66 I use pass-code vaults and auto generate passwords

- YES (1)
- NO (2)

Q67 How do you rate your digital knowhow?

	V. poor	Poor	Average	Good	Excellent

	0	1	2	3	4	5	6	7	8	9	10
My knowledge of digital tools and solutions for a farming business is ()											
My knowledge of digital security issues is ()											
My practical experience of digital tools for farming is ()											

Q68 Rate your competence in the use of digital tools in the following activities.

	V. poor	Poor	Average	Good	Excellent

	0	1	2	3	4	5	6	7	8	9	10
Communication and collaboration ()											
Selecting and setting up technology ()											
Planning and organisation ()											
Monitoring ()											
Analysing and interpreting data ()											
Supporting decisions and actions ()											
Managing data security and online safety ()											

Q69 Rate your attitude to digital agriculture. E.g. totally disinterested would = 0, neither disinterested or passionate = 5 and very passionate = 10

0	1	2	3	4	5	6	7	8	9	10

Disinterested to passionate ()	
Frustrated to excited ()	
Disillusioned to enthusiastic ()	
Pessimistic to optimistic ()	
Scared to confident when using ()	

Q70 Which version of the self-assessment did you prefer?

◯ Version 1 - 84 yes no questions (1)

◯ Version 2 - this version (2)

Q71 Please add any comments about this version.

____

____

____

____

____

Q72 How many minutes did it take you to complete this self-assessment?

____

Q73 Please ensure you add your name and email for cross validation. All data is treated in confidence.

____

End of Block: Default Question Block

Appendix G: Farming Businesses Digital Process Maturity Tool

Farming Businesses Digital Process Maturity Tool

V2

Note numbers in brackets = code not score

Q1 If completing on a mobile phone try rotating to landscape view.
The following questions are designed to help identify how your business currently operates (NOW) and with change how you would like to operate in the future (DESIRED).
Each statement is designed to reflect but not exactly match your current or desired approach to managing key aspects of your farm business, so pick the one you feel is closest. You might already be achieving your DESIRED level of operation, so then select the same statement as for NOW.

Q2 Financial records

	NOW	DESIRED
	NOW (1)	DESIRED (1)

Records are kept as hardcopy in ledgers etc and only loaded on a computer by a bookkeeper/accountant. (1)		
All accounts, invoices etc are electronically recorded to a spreadsheet or financial software (2)		
The records in the financial software can be integrated with management records for analysis (3)		
Actual financial data is automatically analysed against benchmarks and targets. Problems and required actions are flagged (4)		

Q3 Management records

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Most management and production records are written in notebooks and not recorded on the computer. (1)		
Management and production records are transferred from notebooks or directly entered into spreadsheets or farm management software (2)		
Input, output and activity records including the plant and equipment used are recorded directly into management software. (3)		
Automated systems enable management data to be collected and stored automatically (4)		

Q4 Asset management

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Major assets have names but recording is not consistent e.g. Flock 1, Flk 1. (1)	☐	☐
Major assets have standardised naming that is recorded in a reference document (2)	☐	☐
All assets and people are given a unique identify code to enable cross platform data analysis of efficiency, performance etc (3)	☐	☐
All assets are barcoded and actions of individuals and their use of assets (machinery, inputs etc) can be automatically logged via a barcode reader in wearable technologies (4)	☐	☐

Q5 Business systems

	NOW	DESIRED
	NOW (1)	DESIRED (1)
There is a computer in the farm office, but is only used by managers/owners (1)	☐	☐
All members of the team have access to a computer/tablet or smart phone. (2)	☐	☐
All team members have a computer/tablet or smart phone on which they entre data into the management system. (3)	☐	☐
All team members have wearable technology and all machines have some degree of automation. (4)	☐	☐

Q6 Connectivity

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Connectivity is only required for mobile calls/texts and web browsing (1)	☐	☐
Broadband is only available at the main office, otherwise mobile data connectivity is used (2)	☐	☐
Where mobile connectivity is poor it has been augmented with boosters in buildings and/vehicles (3)	☐	☐
Integrated area networks have been established to enable remote data transfer across the whole landscape (4)	☐	☐

Q7 Succession

	NOW	DESIRED
	NOW (1)	DESIRED (1)
No formal succession planning has been started. (1)	☐	☐
Succession has been discussed but not finalised (2)	☐	☐
We have strategies & protocols identifying skills and requirements of family members interested in returning to the business (3)	☐	☐
Autonomous systems and remote access solutions allow farm managers to live remotely, enabling family members to return to the business without having to live on/near the farm (4)	☐	☐

Q8 OH&S

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Our approach to OH&S is based on common sense (1)	☐	☐
Activities that are regulated e.g. require licenced operators are the focus of OH&S activities (2)	☐	☐
OH&S is a high priority. Appropriate safety equipment is supplied to all team members. All team members, contractors and visitors complete and OH&S induction. Where licences are required to operate these are checked and recorded (3)	☐	☐
Dangerous, repetitive or monotonous jobs are done by autonomous machines/robots. (4)	☐	☐

Q9 Employee records

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Our team is mostly family members and none has a job description (1)	☐	☐
All team members have job specifications, including roles and responsibilities. (2)	☐	☐
Activities of all team members are monitored, recorded and analysed to improve productivity, efficiency and safety. (3)	☐	☐
Virtual or augmented reality is used to help team members learn new tasks or improve working practices (4)	☐	☐

Q10 Decision making

	NOW	DESIRED
	NOW (1)	DESIRED (1)
The farm is the unit of management for production decisions (1)	☐	☐
The unit of management is by crop type/enterprise, flock or herd (2)	☐	☐
Each paddock, mob or herd is its own management unit (3)	☐	☐
Production decisions are made based on zones/sub paddocks or individual animals (4)	☐	☐

Q11 Planning

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Planning is done on-the-go, meetings are rare and diaries are kept as hardcopy (1)	☐	☐
Annual production plans are established and reviewed through the season. Electronic diaries are used but not shared by the whole team (2)	☐	☐
A universal electronic diary and notebook system is used by all team members. This contains multiple sub diary layers for equipment servicing schedules etc. (3)	☐	☐
When looking at an asset through augmented reality glasses all a current and nearer future tasks for the asset come into view, new tasks can be added and a prioritised task lists are automatically displayed. (4)	☐	☐

Q12 Farm resources

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Printed maps and aerial photos are used to visualise the location of soils and infrastructure etc (1)	☐	☐
Maps of production layers such as biomass, yield, quality are recorded and	☐	☐
Digital spatial layers for soil, topography and infrastructure (gateways, fences, water pipes, weather stations etc) have been recorded and can be integrated with production layers for spatial production management and logistics. (3)	☐	☐
Digital spatial layers for soil, topography and infrastructure (gateways, fences, water pipes, weather stations etc) have been recorded and can be integrated with production layers for spatial production management and logistics. (4)	☐	☐

Q13 Variation

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Variation in productivity across the farm or within the herd/flock has little influence on production management. (1)	○	☐
Variation between paddocks recorded using yield maps or between animal weights is recorded but managed as an average (2)	○	☐
Strategies to minimise variation between units or to maximise production by unit are in place and variation from targets is analysed. (3)	○	☐
All operations use variable rate to match inputs to the desired unit of management - area, soil type, plant, animal (4)	○	☐

Q14 Weather

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Apps and media are used to access regional weather forecasts and actual rainfall data is recorded as hardcopy (1)	☐	☐
Regional weather data is augmented with on-farm weather and/or on-machine station(s). A range of climatic factors e.g. rain, wind temperature are automatically recorded at least daily. (2)	☐	☐
Historic and forecast weather data is integrated into production analysis for forward planning and current weather data is automatically integrated into records e.g. spray or grazing records (3)	☐	☐
Software is able to integrate historic production, price and weather data, with forecast price and weather data to predict best production options. (4)	☐	☐

Q15 Targets

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Production targets are set annually based on past performance (1)	☐	☐
Production targets are based on past performance, seasonal forecasts and improvements in genetics, water use and feed efficiency and reviewed during the year (2)	☐	☐
Production targets are based around price predictions and target returns, seasonal forecasts and continual improvement for each management unit and new predictions generated during the production cycle (3)	☐	☐
Production targets are based around profitability for each unit of management and continuously update to create sales predictions (4)	☐	☐

Q16 Benchmarks

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Little analysis is done of production or profitability from year to year (1)	○	○
Comparisons between production and profitability are made against previous years for our business. (2)	○	○
The farming enterprises and the farm as a whole are benchmarked against similar businesses/production systems (3)	○	○
Benchmarks are continuously updated and reported at your nominated time interval to compare against the same time point in a previous year or timeframe (4)	○	○

Q17 Inputs inventory

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Stock on-hand is manually counted or estimated (1)	○	○
A detailed inventory of stock is maintained in the management recording system but changes are input manually (2)	○	○
Barcodes and weigh cells are used to automatically upload inventory data and critical stock levels for inputs and out of specification uses automatically flagged (3)	○	○
Input and output inventory data is automatically recorded and production efficiencies analysed. (4)	○	○

Q18 Logistics

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Operating systems are kept as simple as possible to make life easy (1)	○	○
Production targets are the main driver of how we farm (2)	○	○
Production targets, equipment requirements and operating processes are just some of the layers analysed by management to try an make the business as efficient as possible (3)	○	○
Software is used to continually monitor the efficiency of operations and recommend improvements to managers and operators. (4)	○	○

Q19 Prices

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Production is sold when it is harvested/ready for market, irrespective of price. (1)	○	○
Prices are regularly monitored and a combination of cash sales and forward contracts are used to minimise price exposure (2)	○	○
Prices are monitored at least daily; optimum markets are captured by combining stock and target production data (3)	○	○
A diverse range of marketing opportunities - cash, contracts, options, currency trading etc - are continuously analysed using automated market intelligence data streams. Outputs are bought, sold, and blended to maximise returns via the most appropriate marketing opportunity. (4)	○	○

Q20 Stock control - outputs

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Output stock is estimated and only confirmed by sales receipts (1)	○	○
For stock control, sales receipts are cross referenced to estimated sales values, tonnes, kg per head etc. (2)	○	○
Barcodes and weigh cells are used to monitor output stocks which are manually allocated to marketing opportunities (3)	○	○
Remote sensors continually record production parameters for outputs in storage and in the paddock. These raise alerts when critical levels/targets are reached. (4)	○	○

Q21 Traceability

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Traceability is not considered an option with bulk commodities (1)	○	○
Our management records enable a limited level of traceability (2)	○	○
Traceability can be achieved to the nominated unit of management - e.g. paddock, bin or mob, individual animal using barcodes and electronic tagging. (3)	○	○
All outputs can be tracked using advanced tracing solutions e.g. DNA or implanted biodegradable tag (4)	○	○

Q22 Quality

	NOW	DESIRED
	NOW (1)	DESIRED (1)
Management for quality is secondary to production/yield (1)	○	○
Production and quality are both important but management prioritises total output (2)	○	○
Quality and meeting market requirements is more important than production to maximise return (3)	○	○
Outputs are regularly non-destructively measured on-farm for quality during the production cycle, and management actions recommended. (4)	○	○

Q23 Quality assurance (QA)

	NOW	DESIRED
	NOW (1)	DESIRED (1)
No recording system is used to support quality assurance QA (1)	○	○
QA is only a bi-product of production activities via compliance records for pesticide/vet & medication records. (2)	○	○
QA is a pillar of our production and marketing strategy and linked to traceability. (3)	○	○
All production, irrespective of unit of management/marketing can be supported with detailed QA certification. (4)	○	○
All production, irrespective of unit of management/marketing can be supported with detailed QA certification. (5)	○	○

Q24 Rate the importance of these statements about data management

	Not at all important	Slightly important	Moderately important	Very important	Extremely important

	0	1	2	3	4	5	6	7	8	9	10
In your business how important is calibrating equipment ()											
In your business how important is validating data, ground truthing etc ()											

Q26 Which datasets do you already combine for analysis - select as many as relevant

	Production (30)	Financial (31)	Marketing (32)	Environmental (33)	Compliance (34)	None (35)
Production (1)						
Financial (2)						
Marketing (3)						
Environmental (4)						
Compliance (5)						

Q52 Rank the level of importance of each dataset to your business

	Not at all important	Slightly important	Moderately important	Very important	Extremely important

0 10 20 30 40 50 60 70 80 90 100

Production ()	
Financial ()	
Marketing ()	
Environmental ()	
Compliance ()	

Q27 Please confirm your Name

____

End of Block: Default Question Block

Appendix H: The tasks associated with digital maturity

A use case for flood irrigation based on Wang et al. (2020)

Stage	Actions	Core Function & Focus activity
Manual/ analogue	*The decision to flood irrigate is based on experience, visual observation of crop the growth stage and condition, how much rain has fallen (rain gauge and soil moisture meter), when the crop was last irrigated, forecast rain events and water allocation remaining. Valves are opened and closed manually Water is pumped by a mechanical pump. The decision to stop irrigating is based on time and availability to return to manually turn the valve off and on observing water exiting into the end drain.* *The whole block is irrigated as one area.* Irrigation records are recorded on paper and calculations of use, water use efficiency and availability are done manually.	**BUSINESS ADMINSTRATIO N** Management records Asset management **PRODUCTION AND RESOURCES** Decision making unit Input/variation management Weather Performance monitoring
Digitised	*Irrigation is still applied by flooding the whole block based on the same observations and measurements used in the manual system but these are fed into irrigation software to establish a rate and irrigation period. As not all factors required for the calculation are measured, some figures will be estimated and based on rules of thumb.* *This software also stores data on water used by date. Pumps continue to be mechanical and started and stopped manually.*	**BUSINESS ADMINSTRATIO N** Management records Asset management Business systems **PRODUCTION AND RESOURCES** Decision making unit Input/variation management Weather Performance monitoring

Digitalised/ precision	*The single block is divided into irrigation areas based on soil water holding characteristics. Each block is fitted with a soil moisture probe which might be read remotely.* *Data is manually entered into the software for each block, increasing the number of calculations.* *Irrigation scheduling is produced by block. Allocation is controlled by an electric pump and electric valves for each block. Each valve can be switch on remotely by software controlling an electronic pump. Valves are switched off automatically when water is detected by a sensor in the end drain. Irrigation records are stored digitally as in previous stage but can be accessed remotely via an app as the irrigation software is connected via the Cloud.*	**BUSINESS ADMINSTRATION** Management records Asset management Business systems <u>Connectivity</u> **PRODUCTION AND RESOURCES** Decision making unit Input/variation management Weather Performance monitoring <u>Inventory</u>
Digitally transformed	*More sophisticated irrigation software is used which has data upload and download capability. This automatically gathers all the required data including rainfall from a connected weather station, forecasted rain from connected weather models, soil moisture from digital moisture probes, crop condition/water requirement from tensiometers and NDVI images. This software controls the pumps and valves and is able to respond to changing conditions, e.g. areas with poor infiltration can be irrigated more frequently with less water per irrigation.* *Crop conditions, yield and quality information can be shared with potential buyers/marketers, harvest contractors and carriers for logistics planning.* *The software calculates remaining allocation and WUE providing a detailed record for current and future planning of water purchases or sales.*	**BUSINESS ADMINSTRATION** Management records Asset management Business systems <u>Connectivity</u> **PRODUCTION AND RESOURCES** Decision making unit Input/variation management Weather Performance monitoring Inventory <u>Planning and targets</u> <u>Logistics</u> MARKET ISSUES <u>Contracts</u> <u>Stock control</u> <u>Quality assurance and control</u>

Note. As digital maturity increases the number of interlinked data sources increases. Focus activities which are underlined are not part of the previous stage.

Appendix I: Word Cloud Analysis

100 most frequent words in Video responses over 4 letter words – Names and Product Brands and researcher's questions excluded

Version 3 –100 top 3 letter plus names removed as well as key unnecessary words – important, and Manager removed

Appendix J: Codebook—Commercial Providers Barriers

Nodes include negative and positive comments

Name	Description
Connectivity	Telecommunications. Wi-Fi networks, Connectivity solutions. Exclude connectivity between people, only relates to technology. Telematics, telemetry. IoT
Awareness-con	Generate understanding of connectivity options
Desire - con	Informing user of potential solutions to enable connectivity or overcome connectivity limitations
Knowledge-Con	Offline, native apps, low data transfer needs.
Need-con	Identification of why growers should change/adopt connectivity solutions. Understanding of connectivity solutions used and limitations experienced by farmers
Success-con	Good coverage, low latency, reliable connectivity
Data analysis and DST	Use of data to support decision making. Analysis tools. Decision support tools. Data interpretation. On and off farm generation of data. Number crunching but exclude if referring to calculating financial value. Actionable data Exclude compatibility and interoperability Aggregation of data
Awareness-DST	Opportunities for data analysis using digital tools. Benefits of using data and analysing.
Desire-DST	What can supplier offer to meet needs of data

Name	Description
	analysis. Simplicity
Knowledge	
Need-DST	How data is being used, or the data they want to use. Problems being addressed by having data. Current systems used for data analysis. Why data is not already being used/analysed.
Data availability	Are the datasets there, does the data exist? FAIR data standards Can the same datasets be accessed by different apps. API use, Cloud sharing and attitudes to this. Software interoperability, compatibility., interoperability. Foundation datasets. Data sharing Open source
Awareness-DA	Sources of data and why they are important to farmers or advisors. Free versus subscription data collection, collation and storage. On and off farm generation of data. Data formats, compatibility Data quality and accuracy
Desire_DA	How data and systems to collect data support a farming business
Knowledge_DA	How having data or collecting data is impacting on business, business process
Need-DA	Types of data farmers are saying the use and need. What datasets need to be integrated and why. Attitude to use of data. Software/app required to collect data – single or multiple. Ability to integrate with current systems. Ease of transition to new data collection systems. Ease of access. Constant access Exclude references to ecosystem.

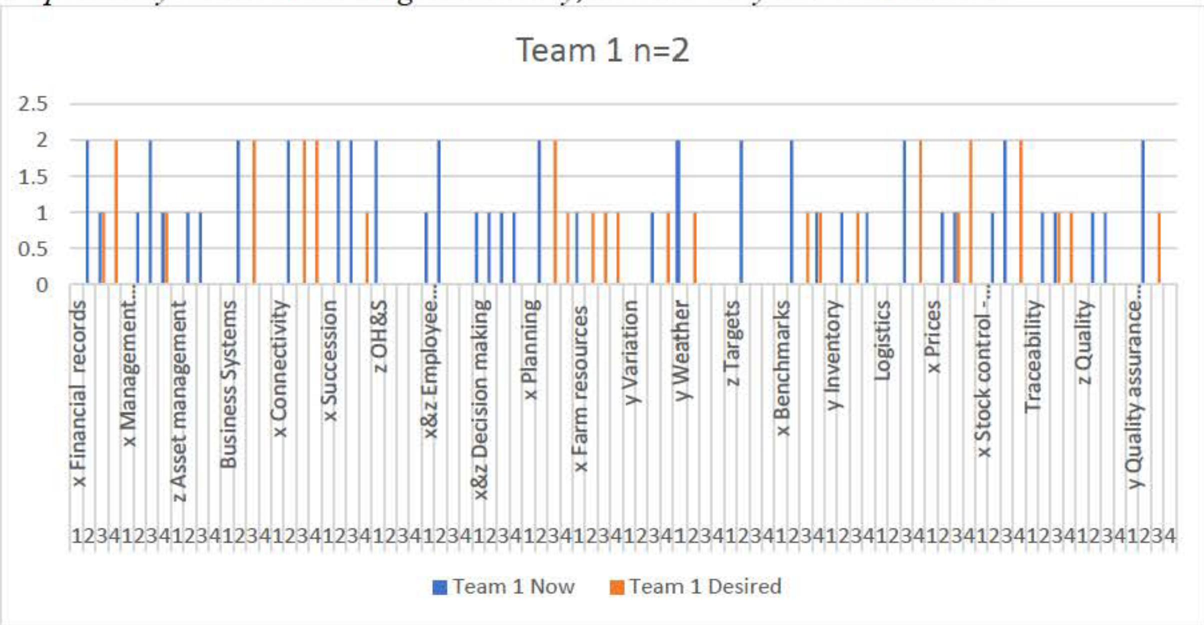
Name	Description
Digital Literacy	User knowledge and skills requirements to use a technology. Understanding of the potential of using technology. Knowledge, skill and attitude - limitations preventing the use or greater use of digital solutions. Available training and support. After sales.
Awareness - DL	Ease of use. Intuitive, user interface, Use of specialists, contracting in require skills.
Desire-DL	showing value, explaining uses, digital language
Evaluate -DL	Farmer ability to make decisions about technology or ways to support farmer/buyer decisions/choices. Ability to use data to support on-farm decisions.
Knowledge-DL	On-going training and support provided. FAQs. User groups, after sales service, involvement with Demo farms, TAFE and other courses.
Need-DL	Current and desired use of technology by farmers and trusted advisers. Current frustrations over inability to use technology. Confidence and lack of in use of technology. Simplicity. Understanding risk around data sharing
Ecosystem	Aggregation of data. Data community, sharing of APIs all parts of the system connected. Dataflows, workflows using multiple softwares, technologies
Individuality	Individuals, diversity of people and systems, every farm is different.
Influencers and	People – young, kids, children, digital natives. Old

Name	Description
Influences	(negative), experience, education, women, wife, accountant, agronomist, specialist, neighbours, other users. Leaders, peer groups, champions. Social proof. Research results. Relative advantage of system – simplicity/complexity
Communication (builds knowledge)	Media, social media, twitter, face to face. Via third parties Use cases, case studies. Exclude training and support. Language used. Target audiences
Time	Demands on time, time to make work, to use. Valuing time, other uses =time better spent, priorities. Saves time Change over time. The right time, timing, industry maturity Adoption is a journey
Trust & legal	Trust that the product will have longevity, that product owners will not use your data. Clarity of legal agreements and ability to opt out. Regulatory requirements around data sharing.
Awareness-T&L	Clear simple data agreements. Description of data tenure. Data agreements.
Desire-T&L	Development of trust and confidence in the technology product or service. Minimising risk
Need-T&L	Understanding of who can use farm generated data and what for. Data privacy. Data ownership. Longevity, continuity on-going product life. Access to data after stop subscription. Trust and confidence in the accuracy and value of data, technology product
Value proposition	Value compared to other priorities, opportunities.

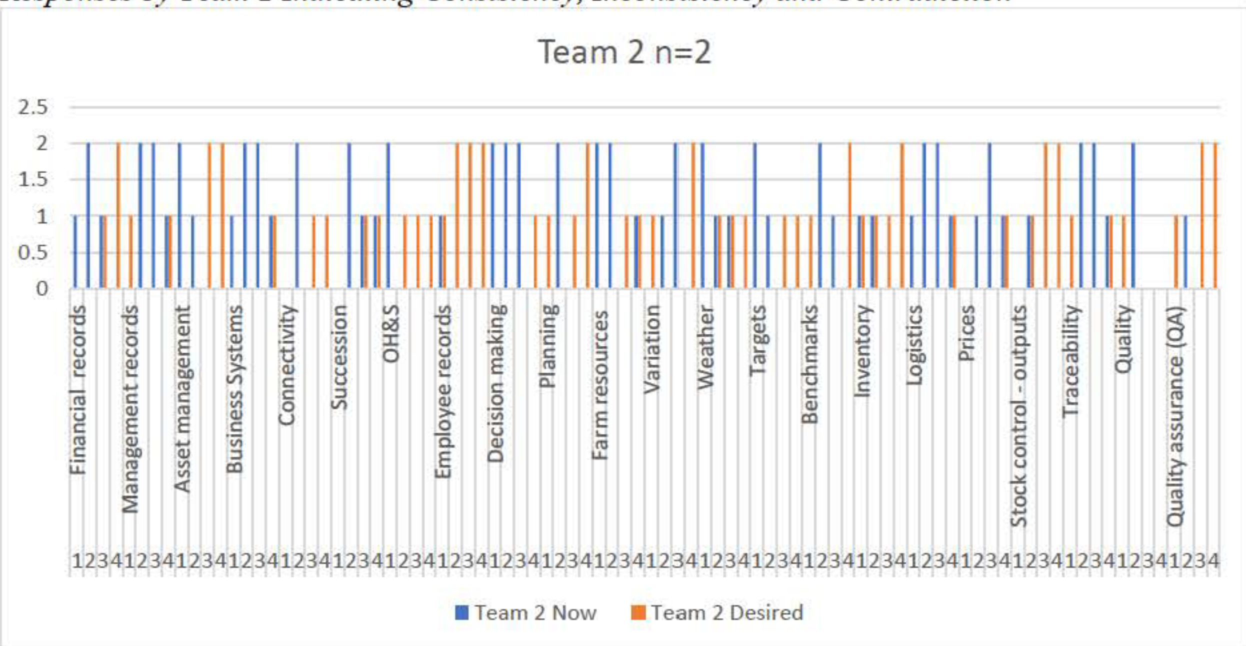
Name	Description
	Financial value or issues to do with cost, cost benefit, return on investment. Potential benefits excluding those relating to other parent codes.
Awareness-VP	Solutions need to be cost effective and clearly demonstrate value. exclude Subscriptions, user interface
Desire-VP	Solutions need to show considerable benefit over current system and other options. Provision of ecosystem, connection. Product displacement by new. Value of data to others 3rd parties
Evaluate_VP	Use of free trials, (exclude provision of free trials) comparisons with current methods, compatibility with current system.
Knowledge-VP	Support to initiate and implement change – provision of free trials. Demo farms/dummy farms. Exclude use of free trial. scale
Need-VP	Attitude to change, risk and importance of technology. Requirement for ecosystem, single data entry, minimal data entry. . Use of technology or service bring a financial benefit. Use of the technology or service makes life easier, safer, better. Cost benefits.
Success-vp	What is the required outcome. Other options to achieve same goal. pick and mix selection. subscriptions

Appendix K: Visual Representation of Consistency/Inconsistency of Responses to the DPM by Team

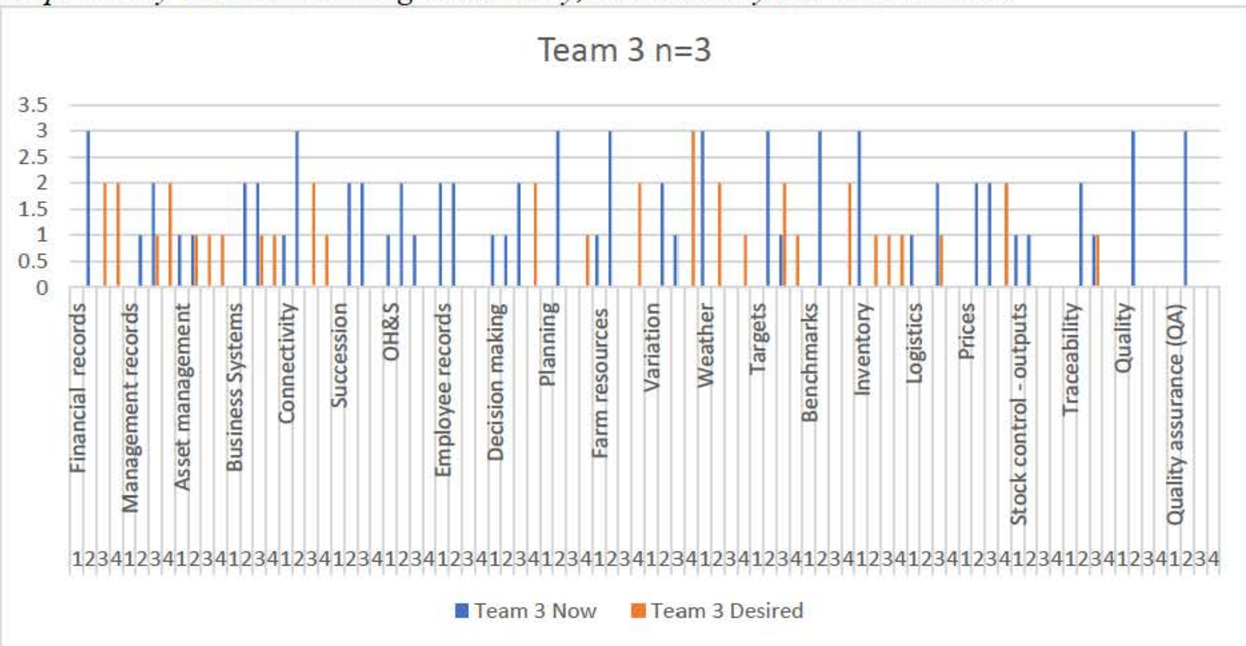
Responses by Team 1 Indicating Consistency, Inconsistency and Contradiction



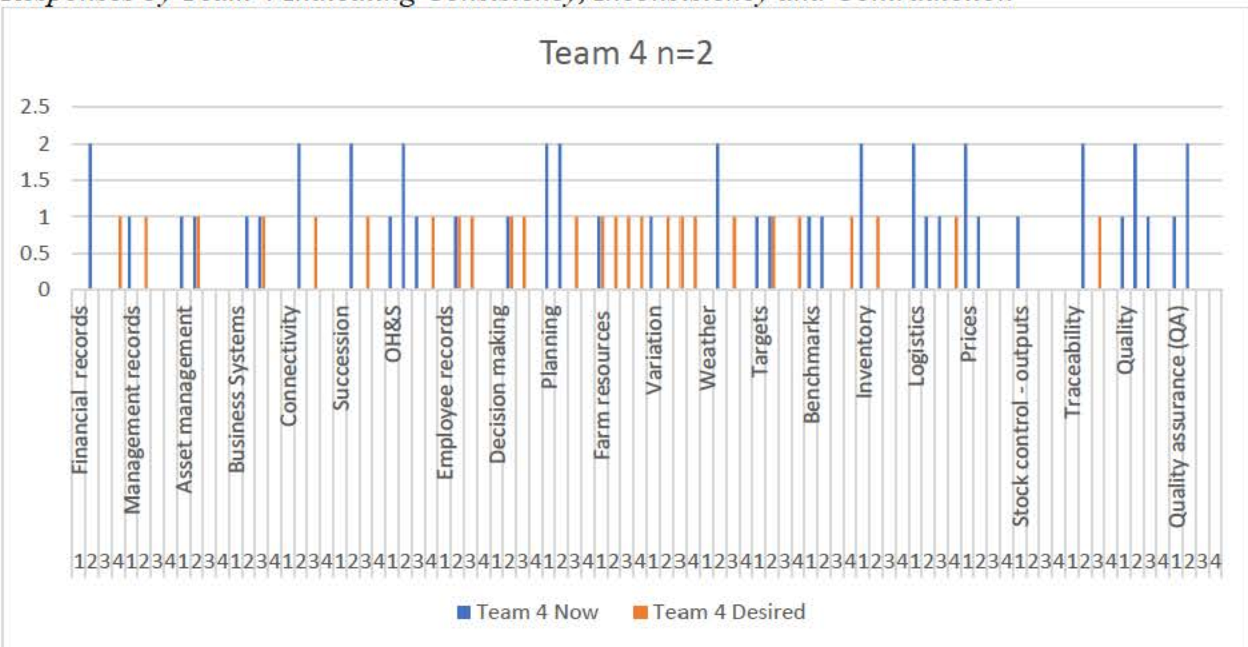
Responses by Team 2 Indicating Consistency, Inconsistency and Contradiction



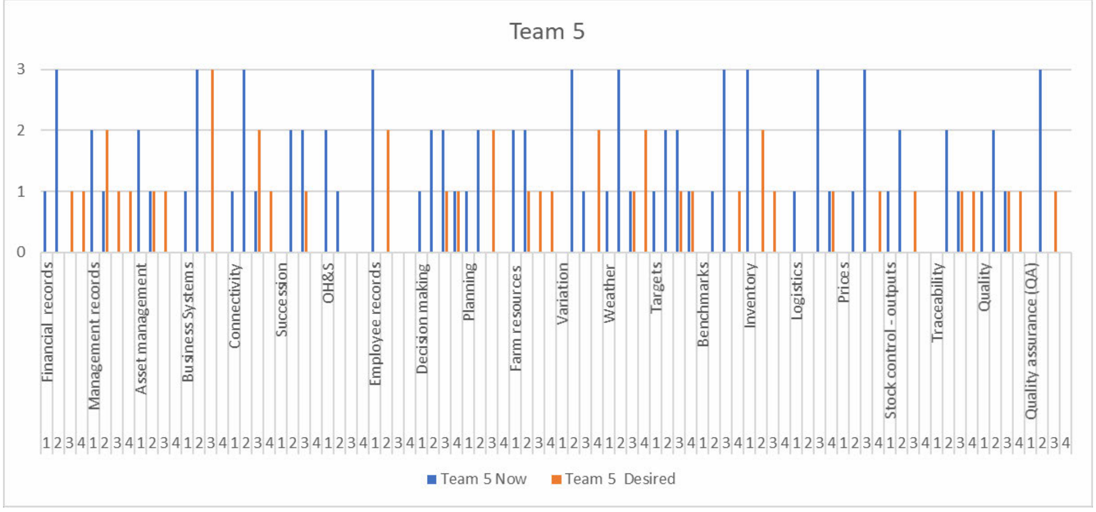
Responses by Team 3 Indicating Consistency, Inconsistency and Contradiction



Responses by Team 4 Indicating Consistency, Inconsistency and Contradiction



Responses by Team 5 Indicating Consistency, Inconsistency and Contradiction



Appendix L: Overview—Accelerating Precision Agriculture to Decision Agriculture - Enabling Digital Agriculture in Australia

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