research report

April 2016

Australian Farm Institute

The Implications of Digital Agriculture and Big Data for Australian Agriculture

Grain Growers
Real benefits. Real results.

Australian Government
Cotton Research and Development Corporation

Dairy Australia
Your Levy at Work

ISBN 978-1-921808-38-8 (Print and Web)

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Farm Policy Research Institute

The Australian Farm Institute

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Publication Data

Keogh, M & Henry, M (2016), *The Implications of Digital Agriculture and Big Data for Australian Agriculture,* Research Report, Australian Farm Institute, Sydney, Australia.

ISBN 978-1-921808-38-8 (Print and Web)

Design and Production: Australian Farm Institute

Printing: J.A. Wales Printers, Alexandria

Foreword

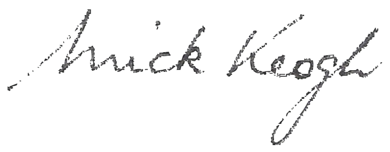
Agriculture has experienced two major revolutions over the past century. The first was the mechanical revolution that occurred in the years between the first and second world wars, during which time horsepower was replaced by mechanical power, with dramatic improvements in productivity. The second was the scientific revolution (often referred to as the green revolution) which occurred over the period from the late 1960s to the late 1990s, and involved the application of well-developed science to the sector, again resulting in significant productivity increases.

It is probably reasonable to argue that agriculture is now undergoing its third major revolution, the digital agriculture revolution. This revolution has been made possible as a result of the dramatic reduction that has occurred in the cost of digital and computer technology, and the adaption of this technology in farm implements and farm monitoring applications.

The potential impact and implications of the digital agricultural revolution are still quite unclear, although rapidly developing. Digital technology and data applications are emerging to support farm management decisions, maintain and report on biosecurity issues, support quality assurance and credence systems, map and analyse land use and crop performance, monitor and manage water, and to track markets and transact sales and purchases.

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

The research reported here involved a detailed analysis of global developments in digital agriculture, and consideration of what will be needed in Australia to ensure that the undoubted benefits that are available will be quickly realised.



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April 2016

Executive summary

The development of farming machinery and digital technology that is able to generate objective information about the status of soil, water, crops, pasture and animals is quickly changing the way in which farm businesses can be managed in Australia. The emergence of digital agriculture, and the potential this creates for the application of big data analytics in agriculture, signals the initial stage of a fundamental change away from the skill-based farm management systems that have prevailed until present times towards a more industrialised model of agriculture where decisions are based to a greater degree on objective data.

The earliest stages of this change occurred in the row and broadacre cropping sectors in the early 1990s with the development of global positioning system (GPS) guidance systems, which were then augmented with autosteer technology and grain harvester yield monitors. Subsequent developments included seeder and fertiliser applicators with the capacity to vary application rates within a field. More recently, software applications and cloud data storage facilities have enabled the resulting data to be captured, stored and manipulated, and then used in decision-support tools to guide farm management decisions.

Digital agriculture applications have also emerged in the livestock and horticulture sectors, including, for example, electronic livestock identification systems, genomics, automated milking systems, automated livestock weighing platforms, telemetric irrigation and water management systems, remote sensing technologies, and instruments for the automated collection of weather and climatic information.

The use of digital agriculture systems to implement more intensive and data-driven farm management decisions enables farmers to economically change from paddock and herd average management, to square metre and individual animal management, with reported subsequent increases in farm productivity. While the extent of productivity gains vary across different agricultural production systems robust analyses report gains of the order of 10% to 15% in cropping systems, with about half the gains coming from input efficiencies, and the other half from increases in output. The deployment of digital agriculture systems in livestock industries is generally less advanced, and therefore estimates of possible productivity benefits – while significant – are yet to be properly validated.

Although bringing the promise of important productivity gains, digital agriculture also brings with it questions about the ownership of, and use to which, digital information obtained from a farm can be put. The service providers that are marketing digital agriculture systems and data storage platforms for farmers are all commercial service providers and, as is the case more generally in relation to digital information, there is a lot of uncertainty about the rules which govern how this new digital environment should operate.

Generally speaking, digital information generated by machinery and technology used on a farm is owned by the farmer, although the 'Conditions of Use' agreements that are routinely signed by computer software users when they first register or use a particular application typically curtail the user's data ownership rights, and create exceptions which enable the software provider to use the data in different ways, and often to make that data available to third parties.

Developing an appropriate regulatory environment which protects a farmers' ownership rights over farm data is a complex task. Farm machinery manufacturers typically reserve the ownership rights to machinery performance data, and accept some degree of control by farmers over the ownership and use to which digital farm production data can be put.

Concerns about the misuse of digital agriculture data by service providers has led to the development of Codes of Practice or the strengthening of privacy regulations in the United States (US) and New Zealand, with a focus on limiting the uses of data to those agreed to by farmers (who are considered the owners of the data). Complexities arise in situations where farm data is transferred to third parties (such as agronomists or livestock advisors) and also in the case of remote sensing data obtained via satellite or drone, over which farmers have no control or rights. Despite these uncertainties, workable arrangements appear to be emerging that are not overly restrictive for service providers, and which give sufficient confidence to farmers.

Digital agriculture and related big data applications are more advanced in the cropping sector of the US than is the case in Australia, and are generally more developed in the cropping sectors than in the livestock sectors. After an initial phase during which service providers attempted to develop closed proprietary systems to encourage greater product loyalty, what has emerged in the US is a commitment to open access data arrangements, whereby data obtained from different types of machinery is able to be used on multiple different software platforms, and readily transferred between these. As a consequence, competition has emerged in the provision of data storage and management platforms, and a competitive software market has also developed. Different systems cans be used by farmers, irrespective of the particular brand of machinery that they are using, or the storage platform on which their data is held. In addition, these open access data arrangements permit farmers to transmit their data from one service provider to another, with very little loss of functionality.

Digital agriculture holds the promise of significant productivity benefits for Australian farmers, although the systems and platforms may not develop in Australia to the same extent that has occurred in the US. This is because developments in the US have been based on the public availability of detailed soil maps; public access to high-density weather data; the presence of a comprehensive mobile telecommunications network throughout key cropping regions; and the presence of large-scale commercial agribusiness service providers which have been prepared to invest in the development of these systems.

Australian agriculture will benefit from the technology 'spill-in' arising from developments in the US, with imported farm machinery now routinely equipped with the digital control and monitoring systems that have been developed in the US.

Whether the computer software systems and data storage applications that become available to Australian farmers will be modified to suit Australian cropping systems remains to be seen, and there has only been limited development of 'off the shelf' systems for the livestock industries.

There are a range of initiatives that can be adopted by the agriculture sector in Australia to facilitate the more rapid development of digital agriculture systems, and these are detailed in the following recommendations arising from this research.

Recommendation 1:

Australian agricultural industries, Australian agricultural research agencies and relevant IT, telecommunications and software organisations should collaborate in the establishment of the Australian Digital Agriculture Forum, with the broad objective of advancing the development and adoption of digital agricultural applications and systems in Australia.

Recommendation 2:

It is recommended that Australian agricultural industries, agricultural technology providers and digital agriculture platforms and software system providers should adopt as a key principle that the farmers who own the land or livestock from which digital agricultural production data is obtained retain ownership rights over that data. This includes the ability to determine

the uses to which that data can be put, and the persons or organisations which can obtain access to that data. Where contractors and sharefarmers are employed, it is recommended that a standard contract be developed that defines data access protocols for each party.

Recommendation 3:

It is recommended that Australian agricultural industries, agricultural technology providers and digital agriculture platforms and software system providers should commit to open access data protocols, modelled on the standards adopted by the Open Agriculture Data Alliance established in the US.

Recommendation 4:

It is recommended that Australian agricultural industries, agricultural technology providers and digital agriculture platforms and software system providers should support the appointment of a Farm Data Ombudsman to oversee data privacy standards, to establish data use categories, and to audit compliance by providers with industry standards for data privacy.

Recommendation 5:

Australian governments should increase available funding for soil mapping and weather recording stations, and actively investigate the potential for public/private investment models and private-sector collaboration as a mean of improving the soil and climate datasets that are an essential foundation of digital agricultural systems.

Recommendation 6:

Lack of access to mobile telephone and data coverage can be a major impediment to the adoption of digital agricultural systems. Australian governments should increase available funding to augment access to mobile telephone and data networks in rural and regional Australia, and actively investigate the potential for public/private investment models as a means of further enhancing data coverage.

Recommendation 7:

Australian governments and rural research and development corporations should collaboratively develop a strategy to make the detailed data and relevant metadata associated with publicly funded research available in accordance with an open access data protocol, and work to standardise the availability of other relevant information about research trials.

Recommendation 8:

Australian publicly funded agricultural research organisations have a fundamental role in the generation of knowledge to underpin digital agriculture applications, models and algorithms, but should not be involved in the development of commercial software programs or digital agriculture platforms that will be used by farm service organisations or farmers.

Recommendation 9:

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

Table of contents

List of boxes, figures and tables

Glossary of terms

Term	Meaning
Agricultural technology provider (ATP)	Agriculture technology providers (ATPs) is the collective term given to businesses providing both technology and associated data management services to farmers. They include seed or machinery suppliers offering yield-monitoring decision services or decision-support tools.
Big data	Big data refers to the analysis of datasets with sizes beyond the ability of commonly used software tools to capture, manage and process within a tolerable elapsed time (Snijders et al. 2012). It can vary in scope and detail, with some data very granular while other is more general.
Cloud computing services	Cloud storage is a model of data storage where the digital data is stored in logical pools, the physical storage spans multiple servers (and often locations), and the physical environment is typically owned and managed by a hosting company. These cloud storage providers are responsible for keeping the data available and accessible, and the physical environment protected and running. People and organisations buy or lease storage capacity from the providers to store user, organisation, or application data.
Digital agriculture	Since the end of the 1980s technology development has allowed farmers to collect increasing volumes of objective data at an individualised field or animal level. Digital agriculture refers to farm management systems where decisions are taken using an increasing amount of digital information, in order to increase productivity and sustainability.
Information and communication technologies (ICT)	ICT is a broad term used to refer to technologies that involve the use of computers, computer networks, telephone networks and internet networks to manage data and information.
Metadata	Metadata is the term used to describe the nature and structure of data. It describes the variables which are included in a dataset, their respective formats, and other aspects of the 'architecture' of a data file. Metadata is essential to the ability of different software systems and applications to be designed to operate using data from a range of different sources.
National Livestock Identification System (NLIS)	The Australian red meat industry has implemented the National Livestock Identification System (NLIS), a scheme to ensure the quality and safety of beef, pork, lamb, sheepmeat and goatmeat. Each animal and each property is identified with a unique numbers, allowing greater traceability.
Precision agriculture	Precision agriculture started as management principles on cropping farms. The use of electronic sensors and GPS guidance systems on machinery allows farmers to adapt input decisions (fertilisation, irrigation) according to field conditions. It started in 1983 in the US (Zwaenepoel & Bars 1997) with the first technology enabled fertiliser rates to be varied within a field based on soil test and other data.
Variable rate application (VRA) or Variable rate technology (VRT)	VRA refers to a technology that is used to enable the application of inputs (fertiliser, water) within a block or field at variable rates calculated using localised data, in order to adapt the amount supplied to the specific need of the sub-field zone. Relevant rates can be calculated using information registered on a map directly using sensors mounted on the machine used to apply the product.
Positioning system using satellite data: Real-time kinematic (RTK)	Real-time kinematic (RTK) satellite navigation is a technique used to enhance the precision of position data derived from satellite-based positioning systems such as GPS, GLONASS, Galileo, BeiDou, and GAGAN. It uses measurements of the phase of the signal's carrier wave, rather than the information content of the signal, and relies on a single reference station or an interpolated virtual station to provide real-time corrections, providing down to centimetre-level accuracy.

Acronyms

ABS	Australian Bureau of Statistics
ACBI	Australian Centre for Broadband Innovation
ACIPA	Australian Centre for Intellectual Property in Agriculture
AMS	automatic milking systems
APIs	application programming interfaces
APPs	Australian Privacy Principles
ATP	Agricultural technology provider
BMP	Best Management Practices
DNA	deoxyribonucleic acid
FOI	Freedom of Information
FOO	feed on offer
GNSS	Global Navigation Satellite System
GPS	global positioning systems
GRDC	Grains Research and Development Corporation
IP	intellectual property
Mbps	megabits per second
MPI	Ministry for Primary Industries
NBN	National Broadband Network
NDVI	Normalised Difference Vegetation Index
NLIS	National Livestock Identification System
NSO	National Statistics Organisation
OADA	Open Agriculture Data Alliance
OTC	over the counter
PA	precision agriculture
PC	personal computer
PGR	pasture growth rates
PLMTs	precision livestock management technologies
PUC	passive uplink connection
RFID	radio frequency identification
Sedex	Supplier Ethical Data Exchange
Sheep CRC	The Cooperative Research Centre for Sheep Industry Innovation
TDM	total dry matter
UAV	unmanned aerial vehicle
UNE	The University of New England
US	United States
USDA	United States Department of Agriculture
VRA	variable rate application

1. Introduction

The development of farming machinery and digital technology that is able to generate objective information about the status of soil, water, crops, pasture and animals is quickly changing the way in which farm businesses can to be managed in Australia. The emergence of 'digital agriculture' has the potential to enable farm operators to manage farms with a much higher degree of precision than has been feasible in the past, and when combined with the power of modern computers and specialised software, has enabled the development of sophisticated decision-support tools that have the potential to assist farm managers to make better decisions and to manage larger areas of land or numbers of livestock.

The initial developments in digital agriculture involved global positioning system (GPS) enabled machinery that were used to implement systems such as controlled-traffic farming. Subsequent developments included the use of GPS and enhanced harvester monitoring technology to produce digital yield maps. More recently, the development of variable-rate planting and spraying equipment has enabled some crop farmers to increase yields and reduce crop inputs by using variable application rates across a paddock.

The latest developments in this area include harvesting equipment that is constantly connected to the internet and that can relay crop yield and machinery performance information in real-time to an off-farm data storage site or digital application, and variable rate planting technology that can modify planting 'recipes' and fertiliser application rates on a sub-paddock basis. Related developments include the utilisation of unmanned aerial vehicles and satellites to monitor crop or pasture performance remotely. These have also been used to monitor flowering and fruiting in orchards and vineyards.

While much of the development that has occurred involves applications utilised for crop or plant production, digital technology is also increasingly used in the livestock industries.

Applications include electronic livestock identification systems, and the use of these in conjunction with satellite monitoring and robotic meat processing systems to more efficiently manage broadacre livestock and to provide detailed feedback on individual animals. Data about the performance of animals from specific herds or flocks, and the genetic potential of specific breeds or bloodstock lines is also now being collected, and can potentially be distributed widely.

In the more intensive livestock industries including dairy, pigs and poultry, electronic animal identification in combination with digital sensors is being used to detect individual animals' health and reproductive status, to monitor productivity, and to individually tailor feed and medications for specific animals.

The most recent international developments in digital agriculture involve the utilisation of data derived from a large number of individual farms in centrally-managed 'expert systems' which are used to prescribe very specific crop planting and management programs on a field-by-field basis. Historical weather, soil and previous year's production data are used in combination with information about the performance of particular crop varieties to formulate the optimum crop planting strategy at a sub-field level, and this information is then utilised in conjunction with digitally-enabled machinery to vary crop planting, fertilising and spraying across a single field to plant and manage a crop. The crop is then monitored throughout its growth and the expert system can be used to make decisions about fertiliser or pesticide applications. Finally, data obtained from harvest equipment is fed back into the system to ‘close the loop’ and enable further enhancements to performance in subsequent years.

While still at a development stage, the implementation of robotic technology in the dairy and meat processing sectors is also creating the potential to develop similar closed-loop systems, whereby genomics, on-farm production data, and milk and carcass data can all be integrated into a single expert system and used to identify opportunities to enhance productivity or to focus production on specialised market opportunities.

Digital agriculture provides the potential for individual farmers to achieve substantial productivity improvements. However, it also raises a number of issues for farmers in relation to the ownership of data, the ownership and management of systems and platforms hosting that data, the rights that farmers hold over data obtained from their farm, the extent to which data held by machinery companies, farm input suppliers and processors can be sold or transferred to third parties, the uses to which data from individual farms can be put, and even the legal status of that data in the event of litigation or a demand by a government authority to access that data.

The issue of farm data security has become the subject of discussions between United States (US) farmers and their farm input suppliers. Issues that have come under consideration as potentially contentious uses of farm data include people with real-time access to harvester yield data from a large number of harvesters using that information to trade grain derivatives, the potential for farm data to be sold to input suppliers or banks for use in marketing campaigns, or the potential for the data to be accessed by anti-farming advocacy groups or a government regulator in order to mount a campaign or prosecution against an individual farmer.

The aim of the project outlined here is to gain a clear understanding of the potential for digital agriculture to enhance productivity growth in Australian agriculture, and to detail some of the legal and other implications of this development.

Ultimately, it is hoped that the information gathered in this research will assist the agriculture sector in Australia to develop a collaborative framework that clarifies all the associated legal and other implications of the development of digital agriculture, and works towards achieving common agreement about issues that may impede the widespread adoption of these technologies in Australia in the future.

Objectives

1. To develop a clear understanding of the potential for digital agriculture to enhance productivity growth in the Australian agriculture sector.
2. To research and document the full range of legal and other issues associated with the generation, collection and dissemination of digital information derived from Australian farm businesses.
3. To develop, in collaboration with all interested parties, a clear understanding of the legal and statutory implications of the development of digital agriculture under Australian law, and to identify any deficiencies or potential areas of conflict that require resolution in order to remove potential impediments to wide adoption of the technologies.
4. To consider and analyse related issues such as skills capacity, training needs and telecommunications infrastructure that may act as an impediment to the potential adoption and development of digital agriculture in Australia.

Methodology

The research undertaken in this project consisted essentially of desktop and industry research.

Research associated with the first objective involved a search of available published literature on current and future potential applications of digitised information in farm management in both the cropping and livestock industries. Most of the published information available related to crop and horticulture production, although some detailed developments in the livestock industries.

Interviews were conducted with industry participants and researchers both in Australia and overseas in order to gain a clear understanding of both the current and future potential applications of digital agriculture.

During the research and interviews, the focus was on gaining an understanding of the nature of the digital information collected, the way that information is manipulated and stored, the uses to which that information is put, and the potential for the information to be utilised by third parties or for purposes other than assisting farmers with production decision-making.

A related part of the international research involved obtaining a comprehensive understanding of the legal and statutory framework associated with the ownership and use of digital agriculture data in specific overseas jurisdictions. The focus of this work was on the US, given the relatively advanced state of development of digital agriculture in that nation.

The research associated with the second objective involved discussions with relevant government and legal experts in Australia at both the national and state level about existing laws or legal precedents that may have implications in relation to the ownership or use of information arising from digital agriculture. These laws were predominantly those associated with ownership and transmission of digital information, but also involved issues such as:

- the nature of contractual arrangements between the purchasers and suppliers of technology and machinery used in farming
- the rights of individuals in relation to information about their farm collected via remote sensing, and also information relating to input use
- the extent to which digital information obtained from a farm can be accessed by government authorities, third parties or through legal processes for commercial purposes or for compliance monitoring or prosecution.

Throughout the research, the focus was on finding ways to develop some common understanding across agriculture about these issues in order that potential impediments to the widespread adoption of digital farming can be removed, and Australian farmers are given the best opportunity to attain the productivity gains the technologies have the potential to deliver.

Scope

Digital agriculture is relatively well developed in the US cropping sector, and especially within the US corn industry, where it is estimated that up to 40% of growers producing up to 70% of all US corn commonly utilise digital information systems to monitor and manage their cropping activities, and use that information to vary planting, fertilising and pesticide applications within single fields in order to optimise productivity and/or profitability.

Digital agriculture is relatively less well developed in Australia. Industry surveys have indicated that approximately 20% of grain growers have used variable rate fertiliser applications on their crops, but the use of integrated digital information systems and software platforms is much less common in Australia than is the case for the US.

Based on the above, it was determined that the scope of the research associated with this project should encompass a detailed investigation of the development of digital agriculture in the US, as a means of gaining insights into the likely progression of developments in Australia.

It was also considered that, while developments in most livestock sectors lag those in the cropping sectors, the potential for digital information systems to develop rapidly in livestock production, especially the more intensive livestock sectors, is quite large, and therefore warranted close examination.

The scope of the research was limited to digital information associated with farm production activities, and did not include matters such as the availability of financial or health-related information about individuals, as these issues are dealt with or being dealt with by other relevant authorities, and are not specific to those involved in farm businesses.

The research involved an analysis of a range of different technologies, software products and associated digital platforms, some of which are described in the report. The research did not set out to provide a detailed list of all available digital technologies and systems that are being utilised in agriculture. Other publications have done this, and in any event the rate of change that is evident would make such a list redundant before it was published. The inclusion of information about a product or technology in this report should not be interpreted as an endorsement of that product or technology.

Definitions

The terms 'big data' and 'digital agriculture' are commonly used in discussing future developments in agriculture, and it is useful to ensure that these two are clearly defined, as they do not refer to the same thing, but they are related.

Digital agriculture is the term used to refer to agriculture which involves the use of digital sensors and information to support managerial decision-making. The rapidly declining cost of digital sensors has meant that an increasing range of machinery and equipment used on-farm is now equipped with digital sensors that record and transmit detailed objective information about that machine's operations. Machinery that is now typically equipped with digital sensors includes tractors, harvesters, sprayers, seeders, haymaking equipment, livestock weighing scales, robotic milking machines, weather stations, water pumps and irrigation systems. In all of these examples, the machinery or equipment is able to generate large volumes of objective data, and often has the capacity to store or transmit these data wirelessly or to an internet-based storage facility. These, often in combination with GPS technology, enable much more objective and spatially precise information to be generated and used in farm decision-making.

The term 'precision agriculture' is commonly used to refer to cropping practices that involve the use of GPS guidance systems, variable rate seeders, fertiliser spreaders, spray rigs and harvesters. Given the specificity of this term to the cropping sector, it was decided to use the term 'digital agriculture' in this report to avoid confusion, and to clarify what is being considered as the application of digital technologies to a much wider spectrum of agriculture than just the cropping sector.

Agricultural 'big data' is a reference to a related, but different development. The term big data is typically used to refer to computerised analytical systems that interrogate extremely large databases of information in order to identify particular trends and correlations that can subsequently be used in 'expert systems' or probabilistic decision-support tools in order to help users make management decisions.

The most obvious example of the use of 'big data' are the customer loyalty card systems that are operated by both major food retail chains in Australia. The data generated by their store sales are incorporated into very large databases consisting of information about the demographic details and shopping patterns of consumers. These can be interrogated to gain a much better understanding of the purchasing habits of millions of Australian consumers, and the information arising from that analysis can be used to tailor retail offers to the very specific needs of quite distinct groups of consumers.

In the case of agriculture, big data is a reference to the collection and analysis of extremely large datasets derived from digital information systems on multiple farms or in multiple different locations. As an example, a dataset containing the yield results of all the hundreds of wheat variety trials conducted across Australia over the last decade, which also included detailed information about the location of each trial, soil types and test results of each of the trial plots, and the temperatures and rainfall experienced during the growing period for each trial, could be analysed and the results utilised to create a predictive tool to assist farmers in deciding which wheat variety is best suited to their specific location and growing conditions. Such an application would be an example of a decision-support tool developed through the use of big data analytics, and made possible through the use of information derived from digital agriculture.

One of the more challenging aspects of agricultural big data arises from the fact that digital information detailing the performance of a specific crop in a specific paddock in a single year is of very limited value to either a farmer or the industry, yet the same information obtained from multiple crops on many farms over a number of years may be very valuable in the development of computer systems that are very useful in assisting farmer decision-making.

As a consequence, it can often seem to farmers that the digital information that can now be collected relating to their farm, such as a harvester yield map, has little more than curiosity value. Experience in the US corn industry, however, is showing that after perhaps a decade of collecting so-called 'useless' information, the volume of digital data that is available is enabling the development of robust new decision-support tools and enabling changed management systems – specifically the use of variable rate application (VRA) systems – that are delivering significant productivity improvements.

A related concept that farmers often find difficult to understand is that electronic farm data from a single farm, by itself, has essentially no value other than perhaps to the owner. This is because it is able to be instantly duplicated and transmitted, but also because in the absence of contextual information about a wide range of production factors or in the absence of very large amounts of similar data from other farms, there is really few actionable decision that can be made based on that limited amount of data.

Just as data about the purchase decisions of a single 24 year old female supermarket shopper on a specific Saturday morning in November are of very limited value to a major supermarket chain, so the data obtained during the harvest of a single paddock of wheat in Western Victoria during a particular year is also of very limited value. Similar data from many thousands of shoppers or wheat paddocks may, however, have significant value.

The need for large volumes of data, and the lack of value of limited amounts of data, creates some particular challenges in the development of big data applications in the agriculture sector.

2. Big data in the economy

It is not easy to grasp the scope of the changes that big data has caused or has the potential to cause in a national economy. On the one hand there are more and more businesses developing systems to manage, store, analyse and distribute electronic data, which is captured by the growth of the ICT sector. On the other hand, businesses in all of the traditional sectors of the economy are changing the way they manage their workforce and assets in response to the insights that are now available about their relevant markets, as a consequence of the development of big data and digital information systems.

The digital economy contributed $79 billion (or 5.1%) of Australian GDP in 2013–14, (Australian Computer Society 2015) based on the latest methodology used to estimate the rising digital intensity within traditional businesses. The Australian digital economy is growing in significance and is 50% larger in real terms than it was in 2011. If the digital economy was an industry it would be larger than Australia's agriculture, transport or retail industries (Deloitte Access Economics 2015).

According to a recent Big Data Roundtable held in Australia earlier this year, three major factors have piqued global interest in big data. These are:

1. an exponential increase in the amount of data that is being collected with forecasts of continued rapid growth
2. an exponential decrease in the cost of computing (to process data) and networking/sensors (to capture data)
3. increased understanding that big data – particularly when coupled with 'big judgment' (that is, the capacity for analysis and discernment at a commensurate scale, speed and intensity) can fundamentally change entire economies, industries and lives (Davies 2015).

One significant factor in the growth of the availability of data is the increasing tendency of a wide range of consumer and manufactured products to incorporate internet connectivity as a standard part of the product. The resulting 'internet of things' is dramatically increasing the number of things that are connected to the internet, and the volume of data they are generating. Some sense of this growth can be gleaned from the statistic that globally, 23 million cars were connected to the internet in 2013, and this number is projected to grow to 152 million by 2020 (IHS Inc. 2013).

This is creating the opportunity to collect digitised information at a scale that was unimaginable even a few years ago, and to utilise this information in an enormous number of different ways. Everything from daily car traffic flows through tunnels to demand for airline tickets, to human disease management and control strategies are now being managed via the use of big data applications.

The growth of the digital economy and big data is a global phenomenon, and it is creating challenges for policy-makers because of the potential it has to disrupt traditional industries and business arrangements. Markets are changing rapidly in response, with national boundaries becoming less relevant, and disruptive technologies allowing new entrants to challenge previously dominant organisations or business systems. Those that are failing to respond, whether nationally or at the firm level, are falling by the wayside, and national governments are recognising that strategies and policies are needed to facilitate the responses that are required in national economies.

> To unlock the potential of big data, OECD countries need to develop coherent policies and practices for the collection, transport, storage, provision and use of data. These policies cover issues such as privacy protection, open data access, skills and employment, infrastructure, and measurement, among others. (OECD 2013)

There are numerous issues that emerge from the development of big data in national economies that policy-makers are now beginning to grapple with. The notion of what constitutes personal privacy has been altered in ways that were not imaginable even a decade ago, with digital information now able to be used to trace, amongst other things, a person's daily movements, purchasing habits, workplace performance, financial assets and personal relationships.

The development of cloud data storage systems potentially necessitates completely new notions of what constitutes a personal possession, and creates the potential for government surveillance at a level most would find highly intrusive. Finding the right balance between privacy and public safety has become much more challenging, given the potential opened up by smartphones, closed circuit television cameras and electronic tags in vehicles or carried as part of corporate security systems.

The issues and possibilities that emerge from these developments in the wider economy are triggering changes as governments, corporations and individuals attempt to come to grips with the implications of these changes. In some ways, the agriculture sector has been less directly exposed to these changes than some other sectors of the economy due to relatively poor telecommunications' connectedness, and the varied and biological nature of agricultural production systems.

The increasing connectedness of farm machinery, the developments of smartphone-based farming software applications, and the growing interconnectedness of the wider business environment in which farm businesses operate means that the digital transformation of agriculture is now proceeding at an ever-accelerating pace, and businesses in the sector will increasingly need to respond to these changes, just as are businesses in the rest of the economy.

3. The development of digital agriculture

The development of agricultural equipment with the capacity to collect and store relevant digital information represented the initial emergence of digital agriculture in Australia, and as noted earlier this is a necessary precursor to the development of agricultural big data applications. The emergence of internet enabled devices and cloud storage platforms that can readily be integrated with farm equipment has subsequently created an environment from which big data applications can more rapidly emerge.

The big data development cycle relies firstly on the availability of digitally-enabled equipment and the accumulation of digital information of sufficient volume to provide a robust database which can be utilised to develop predictive and probabilistic decision-support tools. A virtuous cycle is then able to develop, whereby the availability of improved decision-support tools encourages more farmers to uptake digital agriculture, thereby increasing the volume of data available which can then be utilised to continue the improvement of the decision-support tools.

Digital agriculture, the initial step in this cycle, first emerged in the cropping sector in Australia in the 1990s, as farm machinery began to be equipped with various digital information systems, including the ability to generate maps of crop yields across a paddock or to store information about water flows and soil moisture levels under irrigation systems. Despite the growing accessibility of this information to farmers, many farmers initially remained uncertain about how to exploit its opportunities (Cook & Bramley 2000).

A review of the literature regarding the adoption of digital agriculture shows the rate of uptake by farmers is increasing after an initial period of low adoption. Surveys conducted by Robertson et al. found that around 20% of Australian grain growers used variable rate application of fertiliser in 2011, up from 5% in 2005 (Robertson et al. 2011).

Previous research indicated that there was a significant gap between the commercially available technology and the level of adoption by farmers. Of course, seemingly slow rates of adoption of new technology are not unique to this technology, nor to the agriculture sector of Australia more generally. For example, in the US in 2011, despite wide availability, harvester yield monitors were used on only 40% of grain crop acres, guidance systems on less than 35% of planted acres (winter wheat) and, variable rate applicators operated on less than 14% of planted acres (Schimmelpfennig & Ebel 2011). A more recent survey in the US state of Illinois revealed that more than 75% of corn farmers surveyed routinely utilised variable rate fertiliser applications, and 40% utilised variable rate planting (Hale Group 2014).

In Australia, the Grains Research and Development Corporation (GRDC) Farm Practices Survey Report provided results from a survey of cropping technology use by over 2500 grain farmers in 2011 (Edwards et al. 2012). The survey indicated that variable rate applications were used on 8.1% of cropland area in that year, and that there was significant regional variation. In 2015, GrainGrowers conducted an Agriculture Technology Survey into the adoption of cropping technologies. The result of that survey was that 17% of responders claimed to use variable rate applicators, although the area over which that technology was utilised was not reported (Grain Growers Limited 2015).

The conclusion from these two survey is that the adoption of variable rate applications is much lower in Australia than is currently reported for the US.

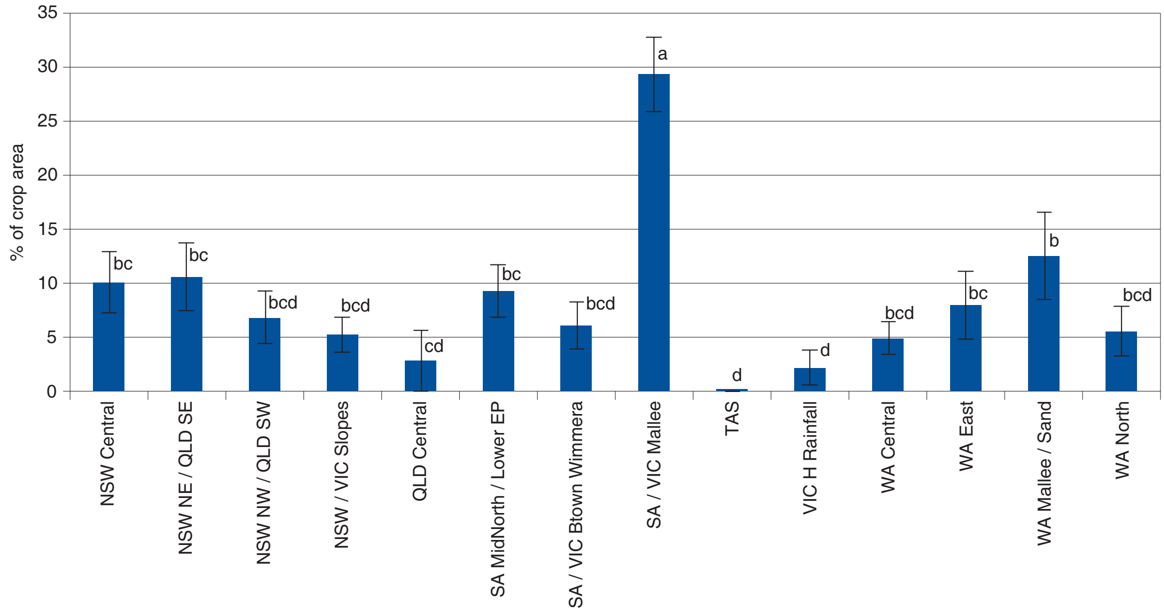

Figure 1: Percentage of regional cropping areas on which variable rate applications were used in 2011.

Source: Edwards et al. (2012).

It should be noted that the adoption of variable rate application (VRA) cropping technology does not necessarily rely on digital agriculture. The authors of the survey reported above noted that some adopters of VRA were utilising soils test and electromagnetic survey results to manually vary sowing and fertiliser rates in response to variations in soil fertility within paddocks.

The adoption rates for digital agriculture in the cropping sector are presumably affected by the fact that accessing the available technology can involve major capital investment in the form of a new harvester, spray rig, seeder (or planter) or tractor. This type of decision is of a markedly different level of significance to a decision about the adoption of a specific new crop variety, for example, where the financial outlay may only be marginally different to that associated with the current variety.

There is an additional barrier to adoption in that to adopt and use these technologies, not only do farmers have to make financial investments, but they may require time to learn new skills. There is also a gap between the 'user' phase of the technology process and the potential benefits farmers can achieve when equipment and data systems are used effectively. This is true for the grain sector and most notably for the livestock sector. This point was frequently mentioned in literature discussing these issues.

There are two opportunities to close this gap. Early learning and education of farmers is one such approach (Eastwood 2008), the other involves the development of improved user interfaces and product integration from manufacturers. There were frequent comments in the literature about the limited use of technology by Australian farmers due to difficulties in integrating software components, problems with data interpretation and using technology to apply agronomic solutions (Jochinke et al. 2007).

Generally, it seems farmers implicitly recognise the need for a data strategy associated with the adoption of digital agriculture or precision agriculture (PA). In interviews many have expressed or observed a reticence to invest in new digitally-enabled technology unless they can see financial benefit or feel capable of deriving one from the resulting data.

This attitude broadly aligns with the recognised need for a data strategy which incorporates data technology into a wider solution rather than a reliance on the technology to drive operational improvement of its own accord (Jochinke et al. 2007).

Estimating the financial benefits associated with the adoption of digital agriculture (specifically VRA in the cropping sector) is a difficult exercise and agricultural economists have not yet come to a common methodology. Case study results from an analysis of on-property benefits from precision livestock management technologies (PLMTs) provided useful information and cost-benefit ratios for specific technologies. The economic benefits were assessed using a subjective methodology to estimate that production and cost saving benefits. The distribution profile for each technology provided data that is to some extent used to estimate the risk of an economic return for each given technology (Swain et al. 2013).

In a report written by the Hale Group (2014) on behalf of Iowa Agstate Farm Group, estimates of potential gains were provided for corn cropping. The study compared the differences in returns and costs between 'innovators' using best available digital agriculture and data for full variable rate cropping systems and farmers not currently utilising VRA, but using precision agriculture technologies.

Estimates listed in the report were as follows:

- Yield gains achieved were between 5 to 10 bushels of corn per acre, which at US$3.50/bushel means a potential gain of US$18 to US$35 per acre gross.
- Improved nitrogen efficiency, reducing costs by US$25 to US$30 per acre.
- Gross savings of US$43 to US$65 per acre.
- Deducting from this the US$3 to US$10 per acre normally charged by service providers for data storage, manipulation and management resulted in net gains of between US$33 and US$62 per acre (Hale Group 2014).

Other studies have examined the costs of investing in digital agriculture technology compared to the costs of conventional farming technology on a whole farm basis. Most found that while digital agriculture tools have the potential to save money for farmers by increasing efficiencies in broadacre cropping systems, the initial time and monetary outlay has always limited its adoption compared to conventional technology (Jochinke et al. 2007). However, Robertson et al. noted that farmers are taking a 'stepwise' approach to digital agriculture adoption whereby they make sequential investments in components such as GPS, yield mapping, variable rate applicators etc. This ameliorates some of the initial outlay requirements. Growing market size and better understanding of farmer requirements are expected to further reduce implementation costs for farmers (Robertson et al. 2011).

Literature on the productivity gains that are estimated to be available as a result of the deployment of big data applications in agriculture is limited due to the relative immaturity of the technology. What research exists tends to focus on the cropping sector and specific technologies that harness more accurate application of inputs or the use of site-specific information to develop models or tools for producers.

The following section examines some of the specific digital technologies being utilised in different sectors of agriculture.

3.1 Cropping

Historically, fertiliser, seed and pesticide input recommendations for crop production were prescribed as a best-fit average for an entire paddock. The advent of variable rate application technology, more intensive soil testing and electromagnetic soil surveys has allowed for greater precision in cropping operations by varying application rates of fertilisers and pesticides within a paddock, and by varying crop planting rates. The result has been an improvement in crop farm productivity, and in the efficiency of water and fertiliser use.

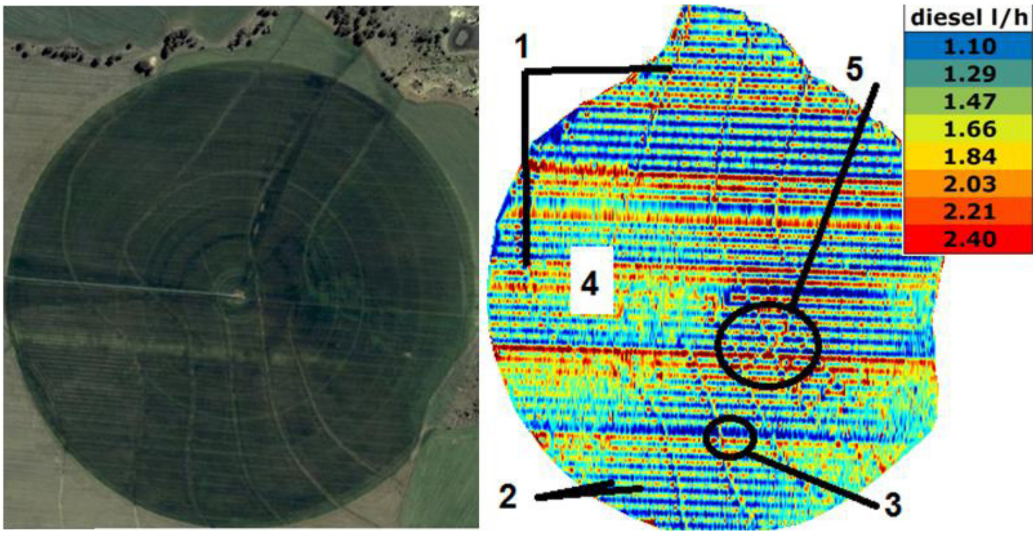

Figure 2: Harvester fuel use map.

Source: AgInnovators (2016).

The relatively intensive use of inputs and machinery in the cropping sector has meant the sector has been particularly receptive to potential productivity gains associated with the deployment of digital agriculture. The size of, and level of investment associated with the US corn and soybean industries has also been an important factor in the level of development of digital agriculture technologies in that sector, with large- and small-scale agricultural innovation and technology companies making very significant investments to develop new technologies.

The cropping sector has realised substantial operational gains from GPS applications that have been progressively adopted since the 1990s. The benefits obtained from the use of GPS and auto-steer systems in broadacre cropping have included the minimisation of soil compaction, the ability to cultivate for reduced disease impact and herbicide dependence, the ability to minimise input overlap and waste, and opportunities to improve soil water management. The use of GPS technologies also makes feasible the analysis of a many additional factors that can impact on the efficiency of input use, and ultimately crop profitability.

An example is the use of maps showing harvester fuel use rates within a paddock to identify particular management issues. Figure 2 shows an example of a novel analysis based on harvester fuel use rates that has identified five separate factors affecting the efficiency of the harvester operation. These were (1) contour banks, (2) slope, (3) weight of the spreader, (4) soil type or steepness, and (5) compaction caused by an irrigator.

The increased sophistication of sensors and internet enabled devices allow streams of data to be captured from cropping operations, including harvesting, spraying and seeding, as well as data obtained from remote sensing via satellites, or obtained via the use of unmanned aerial vehicles (UAVs). Input suppliers and advisors to the cropping sector in the US have been in the vanguard of the development of data applications that enable farmers and their advisors to store the resulting data, retrieve the stored data, integrate various different sources of data relevant to a specific paddock, and ultimately to utilise suitable algorithms to make probabilistic projections about the implications on specific crop management decisions – in particular associated with varying inputs across a paddock.

More recent software applications have included the capacity to retrieve climate and soil data for a specific paddock from public information sources and to integrate this with private production data; and a soil-test gridding system that enables users to map the location where samples have been taken for soil tests, and attach the data arising from soil test results to that same location on the digital map.

In the US the private sector has been leading the commercialisation of digital agriculture via the development of software and hardware tools that assist with the integration of the rapidly growing flow of digital information that can now be generated. At a recent conference convened in St. Louis, Missouri, for example, more than 100 different technology and software providers were present, with a large range of different technologies and data integration products. These included:

- software systems for farmers and their advisors
- software systems for crop input resellers
- UAV control and image analysis software
- digitised irrigation and water management systems
- paddock mapping software
- cloud-based data storage and retrieval services
- software systems that are able to access public climate and soil information for a specific paddock
- major machinery and seed suppliers offering data storage and analysis platforms
- suppliers of digital control systems for a wide range of different types of farm machinery
- suppliers of data integration systems and technologies that enable the transfer of information between different machines and operating systems.

A number of these products are available in Australia – either as part of a package of systems associated with large-scale farm machinery, or as stand-alone products able to be used by farmers and their advisors to manage cropping programs. The different cropping systems that exist and the differences in the availability of public climate and soil data have probably limited the availability and rate of adoption of many of these systems in Australia.

Many of the software systems offered in the US provide data storage and retrieval capabilities, but have only limited capability to integrate available data in a way that supports decision-making by users. This data integration function is still performed 'manually' by crop advisors and farmers, especially when it comes to drawing up variable rate application zones within a paddock (field).

A limited number of services and software systems have developed to the extent that the variety of different pieces of digital information are integrated in ways that assist farmer or advisor decision-making. One of the earliest of these was the service offered by Monsanto called 'Field Scripts'. Crop farmers opting to utilise Field Scripts advised their seed retailer, who assisted the farmers with field mapping, and the retrieval of historical soil test and harvest data relevant to that field. That information was provided to Monsanto, who combined that information with soil, weather and other data (including a large repository of variety trial results) using proprietary algorithms to produce a variable rate 'script' or cropping recipe (on an ipad) that the farmer used in conjunction with a Precision Planter controlled variable rate seeder to plant the corn crop. The crop was then monitored remotely on a number of occasions during the growing season, and the farmers provided with advice on matters such as fertilisers and pest control. Finally, information from the resulting yield map generated during harvest was accessed to close the loop and refine the system for use in subsequent years. According to Monsanto, the crop farmers utilising the service achieved yield gains of up to 20%.

The Field Scripts system was offered for three successive years, and Monsanto reported strong uptake by farmers, and a high level of product loyalty by those who tried the system. The system was discontinued at the end of the 2015 cropping year due to servicing costs and risks, although in its place Monsanto (through its subsidiary the Climate Corporation) has released a range of software products including Fieldview Prime, Fieldview Plus and Fieldview Pro (the latter two being subscription-based systems) that support many of the functions offered via Field Scripts although in a less prescriptive and more user-friendly way.

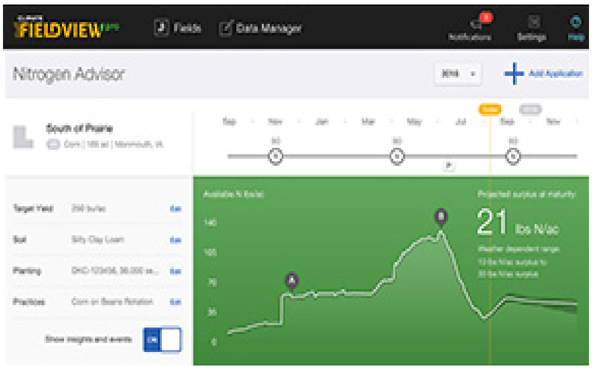

Figure 3: Climate Corporation Nitrogen Advisor.

Source: The Climate Corporation (2015).

The current generation of software provided by the Climate Corporation include decision-support tools that offer advice about the weather, crop variety performance and fertiliser depletion rates, rather than telling farmers what, how and where to plant specific crops. One of the most used developments by Monsanto has been the Nitrogen Advisor within the current Climate/Fieldview software family. This user interface application provides farmers with projections of nitrogen fertiliser depletion in crops.

A user can input the intended nitrogen fertiliser application rate and the software projects forward the rate of depletion of that fertiliser in the soil, based on known soil type and the likely climate (based on detailed historical climate data) for that particular field. This provides users with the opportunity to finetune fertiliser applications, a function that is potentially quite valuable given the relative importance of nitrogen fertiliser as a crop input in the US corn industry.

The application was used to map and make decisions on more than 75 million acres of crops in 2015 (up from 50 million acres in 2014). This represents approximately 45% of all corn and soybean plantings in the US during those seasons. The more sophisticated product, Fieldview Pro, which is only available as a fee-based subscription service, was reportedly utilised on 5 million acres in 2015.

This is just one example of a number of agricultural input suppliers which are collating big datasets and employing data scientists to interrogate them in order to obtain actionable insights. These organisations are also developing computer models of specific components of crop production (eg soil water uptake, nutrient uptake, etc). These can then be used to develop algorithms and models which may not necessarily be perfect at first, but which can be progressively updated as identified gaps in knowledge and information are filled over time.

An opinion common to US industry representatives was that the cropping sector is in the early stages of a data growth curve, whereby in a few years there will be enough environmental (soil, water, temperature, rainfall), production and crop data to start to make use of quite complex decision-support tools. At present, a lack of robust historical yield and input data inhibits the widespread development of analytics products. Crop yield data, for example, is of limited value without records of seasonal rainfall and fertiliser applications.

Most industry authorities consulted agree that at least five years of yield, fertiliser and weather data are needed to make analytics products useful and robust. Many US farmers have purchased new, digitally-enabled cropping machinery during the recent period of relatively high profitability in the US corn industry. It will take several more seasons with this machinery in operation before multi-year datasets become widely available in sufficient volume in order to allow for the rapid growth in accuracy and proliferation of predictive analytical software applications.

The scope of digital products that have been developed for use by US crop farmers is growing quickly on the back of the expanding pool of available digital information, and this growth is also being aided by the availability of comprehensive and granular public data on climate and soils in the US.

An example is Farmlink, a company that had its genesis in harvester leasing in the US. The data analytics business of the company developed from the realisation that the harvesters they were leasing across multiple US states were generating reams of yield data each year, but potential calibration errors meant this data was of questionable value. Farmlink developed standardised harvester calibration systems, and also identified technology that enabled harvester yield data from individual harvesters to be transmitted to a central storage facility. The yield data is then overlaid with weather, soil, topography and other data which allows Farmlink to benchmark farm performance between similar growing environments at the sub-field level – in fact for plots of around 150 square feet.

Using this system, Farmlink believes they now have reliable harvest data from many thousands of fields, which can be used to provide crop advisors with benchmark information to compare the performance of their farmer clients. This information is also being utilised firstly to calibrate satellite imagery, and then to use this to make harvest and production estimates, which it is believed will closely rival the accuracy and timeliness of official government forecasts.

A number of different software support systems are available and currently being utilised in the cropping sector in Australia. SST Software provides a number of different software applications that are primarily targeted at retail crop advisors, enabling them to map clients cropping programs, identify and order required inputs, and provide advice to clients about available crop protection and fertiliser products. This system is used by several major Australian crop input suppliers, and has been used to map large areas of crops over recent years. Software products such as Agworld and Farmware provide some similar capabilities, although the latter also functions as a farm notebook to record livestock activities.

Box 1: Farmlink – TrueHarvest

The following figure is an example of Farmlink's 'Gap Maps' – which enables crop advisors to compare the performance of their client's crops to those of other crop farmers growing under identical soil and climatic conditions.

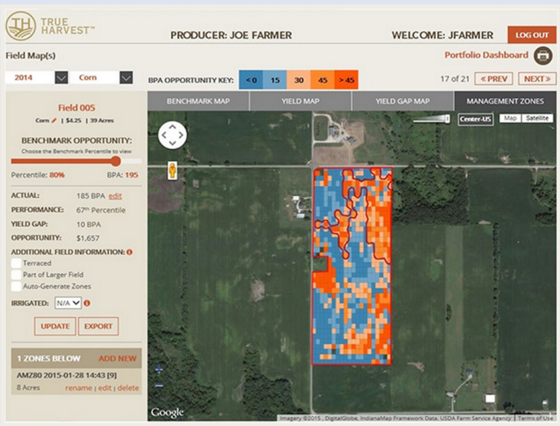

Figure 4: TrueHarvest Gap Map.

Source: Farmlink (2015).

Productionwise is a digital crop and farm management system that has been developed in Australia by GrainGrowers. It includes mapping and information recording capabilities, weather information, chemical and fertiliser record-keeping functions, grain stock and crop gross margin information, and utilises satellite and online climate and soil data to provide vegetation and predicted yield information for each paddock. The system also incorporates a number of decision-support tools that are essentially based on the APSIM crop model, originally developed by the CSIRO with funding provided by the GRDC. The system is also able to be utilised either by crop advisors or farmers. This software system does not as yet include tools to integrate digital data generated from a range of different sources including harvesters, but is undergoing further development.

The ultimate goal of much big data analytics in the cropping sector is to empirically derive optimal crop management decisions based on the analysis of objective farm data. The rate of progress in achieving this is likely to be iterative, as improved computer applications will encourage greater adoption of digital technologies by farmers, which will in turn increase the volume of data available and hence the robustness of the computer applications.

To a degree the rate of progress in the initial stages will depend on the development of ancillary products (such as the Nitrogen Advisor) that deliver value to farmers and encourage them to collect and accumulate digital information associated with their cropping activities.

3.2 Extensive livestock

While to some extent the availability of digital technology associated with the management of livestock enterprises is as advanced as is the case in the cropping sector, the routine use of these technologies, and the development of software platforms to manage the information they produce is less advanced. Individual electronic animal identification systems have been operating in the beef industry in Australia since 2004, for example, but there has not been anywhere near the same level of software or systems development as has occurred in the cropping sector since that time.

Digital agricultural technologies now enable farmers to record numerous attributes of their livestock, such as reproductive state, weight gain, feed conversion ratios and killing-out-percentages (carcass weight as percentage of live weight) that can be used to improve farm management decisions. A recent report by Meat & Livestock Australia (MLA) assessed the areas of greatest potential benefit for beef and sheep livestock enterprises arising from the use of digital technologies (Henry et al. 2012). The research identified the four main areas with the highest productivity benefits:

- soil fertility monitoring for improved pasture production
- feed allocation systems (allocating appropriate quality and quantity of feed to different classes of stock in a timely manner)
- animal production monitoring (monitoring animal weight and body condition to improve reproductive performance and animal growth rates)
- animal disease monitoring (early detection of subclinical diseases to improve performance and welfare).

The MLA report estimated that the potential productivity benefits arising from improvements in farm management, based on selected case studies were:

- 13–26% for soil fertility improvements
- 9–11% for better feed allocation
- 4–9% for animal production monitoring
- 4–13% for animal health monitoring.

These preliminary findings need to be tested and validated in a range of different agricultural industries so that more accurate estimates of productivity benefits can be obtained (Griffith et al. 2013). Other reports from different agricultural industries have identified similar positive productivity benefits from the adoption of digital agriculture.

The figure below illustrates the relationship between a number of farm technology systems and on-farm needs relevant to the southern livestock industries.

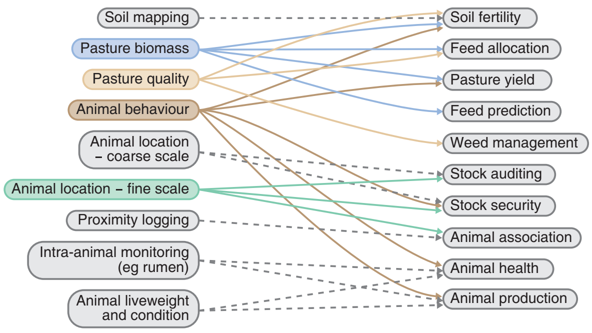

Figure 5: Diagrammatic representation of how various data from technologies may contribute to identified on-farm needs.

Source: Griffith et al. (2013).

Some of the specific digital technologies that are currently available for the management of broadacre livestock are discussed in more detail below.

Auto-drafters and walk-over-weighing platforms

Digital information is now able to be collected on livestock, pasture and the environment using technologies such as walk-over weighing scales, satellite imagery, GPS collars and weather stations. While all these technologies are available, few are in use in commercial livestock production enterprises in Australia, although there is growing interest in the possibility of adopting some of these by larger-scale commercial operators.

Auto-drafting equipment based on animal weight is now commercially available for the beef and sheep industries, however data can generally only be saved on hardware such as a wand via a Bluetooth connection. An integrated telemetry system to upload information in real-time to a user interface via the internet is currently being tested at CSIRO's Digital Homestead in rural Queensland. The project aims to demonstrate and evaluate livestock technologies to enable better decision-making. In the pastoral regions of northern Australia, this technology holds the promise of a substantial reduction in mustering costs for those businesses which rely on controlled waters.

The CSIRO trials also involve sourcing other external farm information such as meat processor pricing schedules, local sale results and weather forecasts. Information is integrated and displayed as a 'dashboard' where data can be accessed by simply clicking on a particular paddock or herd (Delaney 2015). Although actual productivity gains from this project cannot be directly related to farms outside of the project, the results have provided information on certain technologies that proved more economically viable than others.

The average savings from using a walk-over-weighing system were estimated to be around 10% of current mustering costs, the highest of all trialled technologies. It was also estimated that this technology provides an overall average improvement of 2% in gross margins (Swain et al. 2013).

The walk-over-weighing systems can also provide a platform for a range of other sensors including frame height sensors and cameras that deliver digital still images of the livestock, however the accuracy and practicality of this function is not yet determined. Some trial systems have been refined so they can record the weekly weight of individual animals as they walk over the weighing platform. These data can then be cross-referenced with the weight change of the herd as a whole (Brown et al. 2012). This allows producers to identify animals showing signs of aberrant behaviours and can be selectively contained for physical examination. For producers, this information enables them to monitor individual and herd live-weight and weight gains on a regular basis. For animals destined for sale this technology facilitates decision-making by ensuring market specifications are met with respect to live-weight.

Systems which include auto-drafting capability currently cost approximately $30,000. The major cost saving benefits from this technology are related to savings in mustering costs, either helicopter or man hours. Table 1 shows improvements that were made on large-scale beef properties in areas such

Table 1: Estimated benefits from walk-over-weighing and auto-drafting systems.

	Property				
	1	2	3	4	5
Branding percentage (annual % increase on current rate)	65% (2.9)			68% (1.13)	
Carrying capacity for cell (hd) (% increase)					1000 (4.63)
Average daily live-weight gain (kg) (% improvement)	0.3 kg/day (3.5)	0.53 kg/day (3.88)	0.3 kg/day (1.5)		0.4 kg/day (4.13)
Margin per kg ($) (% increase in margin)	$0.30/kg (3.75)	$0.40/kg (3.75)			
Helicopter mustering costs ($) (% reduction in flying costs)	$30,000 (7.5)		$128,000 (14.5)	$96,000 (11.25)	
Labour costs ($) (% saving)				$ 5600 (17.5)	$ 22,500 (7.0)

Source: Swain et al. (2013).

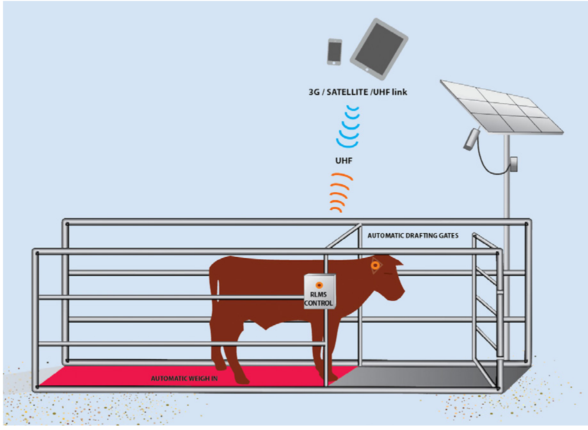

Figure 6: Remote livestock management system.

Source: Ninti One (2013).

as branding percentages, carrying capacity, weight gains, profit margins, and savings in mustering and labour costs (Swain et al. 2013).

Available commercial technology is claimed to be capable of identifying, weighing and drafting individual animals when they step through the station with an accuracy of 96% per pass (see Figure 6) which is estimated to save cattle producers around $68 a head in annual operational costs (Bem 2013). The animal data captured can be readily transferred to downstream management applications and monitoring software capable of delivering further operational efficiency gains (Tru-Test Limited 2016).

The equipment is solar-powered and uses telemetry to transmit data between a remote location and the office of a manager. It takes advantage of water as the primary attractant for livestock by using an obligatory walk-over-weighing facility at water points.

Livestock tracking systems

Technology is now becoming available to assist in locating herds on large properties. The Taggle system employs Global Navigation Satellite System (GNSS) positioning to provide an estimated location of the animal through an ear tag (see Figure 7). The receiving antennas send information to a server that processes the data which is then presented in real-time on an application accessed on a mobile device or personal computer (PC). This information provides almost real-time information about the geo-location of the livestock, potentially preventing theft or loss through straying. The system uses 15 minute sample intervals, with the livestock tags lasting up to an estimated three years based on in-built battery capacity. This also overcomes the battery power challenge of satellite-based location technologies. A Taggle system currently costs approximately $5000 per tower and $20 per tag.

Figure 7: Wireless NLIS animal identification and tracking system to assist with herd management and breeding using Taggle ear tags.

Source: Griffith et al. (2013).

This approach has been adopted at Australia's first SMART Farm, an initiative led by the Australian Centre for Broadband Innovation (ACBI) in collaboration with CSIRO, and the University of New England's (UNE) Precision Agriculture Research Group.

Kirby Smart Farm was one of the first mainland farms connected to the National Broadband Network (NBN) fixed wireless service and broadband which has significantly helped transform the farm's operations. A low cost wireless cattle tracking system

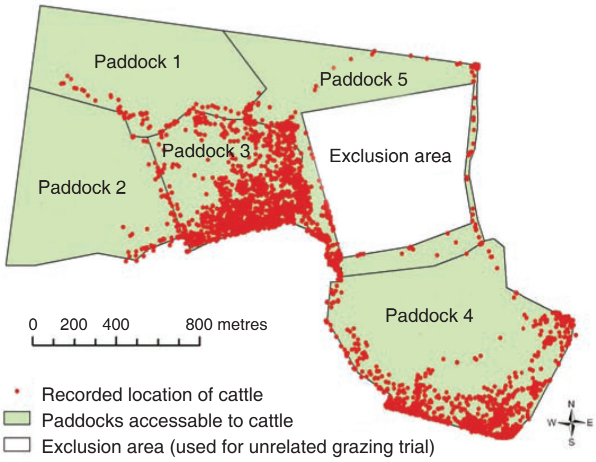

Figure 8: GPS positions of cattle as recorded by UNEtracker collars over 14 consecutive days.

Source: Lamb et al. (2008).

and video-monitoring technologies help monitor individual animal behaviour and location. A smaller number of other sensors such as weather stations and light sensors are also deployed across the farm. The operation utilises radio frequency identification (RFID) devices that can be carried externally on the animal such as an ear tag or internally in an RFID bolus. GPS collar trackers have also been utilised for livestock management at Kirby Farm.

Figure 8 shows a 14 day trial of the tracking collars, where positions of collars recorded and distances travelled per day were calculated.

The use of RFID in combination with automated data capture systems aims at reducing the cost of useful data collection. Currently, the data is often used only at the time of collection for a management decision that is immediately implemented. However the true potential value of data is achieved when it is combined with other information for within flock or herd selection decisions such as culling or feeding and reducing the risk of compromised wellbeing. Basic management systems that are commercially available and commonly used today with RFID include portable handheld/stick readers, permanent readers (fixed into the race), and weigh scale indicators which can display weight and drafting statistics and have the ability to calculate daily weight gains, carcass weight and store tag numbers and condition scores.

The Cooperative Research Centre for Sheep Industry Innovation (Sheep CRC) has been collecting high-quality and large-scale datasets for the industry's Information Nucleus program to help breeders manage expectations about lamb growth rates, particularly for twins and triplets.

The program involved the collection of a comprehensive set of measurements from 20,000 animals and the process of data collection, storage and analysis would not have been possible without semi-automated data collection and the improving ability to transmit, store and utilise digital data. In order to maintain the accuracy of the predictive equations used in the system, it is also necessary to keep measuring subsequent generations of animals to ensure that changes in the patterns of DNA (deoxyribonucleic acid) continue to predict breeding values accurately. The latest development of these data platforms has been the creation of the Ram Buyer smartphone app which was released July 2015. Through the use of predictive algorithms and by collating data from the Information Nucleus Program, there is an opportunity to enhance the clarity and transparency of seedstock markets, and establish true value-based pricing for the sheep industry (Rowe & Banks 2015).

The same data is valuable when it is also used to make better decisions on genetic selection and sharing information through the supply chain. New measurements being developed for carcass grading within abattoirs will primarily be used for carcass sorting and payment grids but will also have considerable value in contributing to information available for genetic selection and feedback to producers in order to improve management and production systems.

The development of cloud and internet computing systems facilitates the development of centralised databases that can be used to ensure that data is available for multiple purposes. Efficient data collection and its effective use have the potential to improve labour productivity considerably. When combined with the benefits of faster genetic gain and better livestock management, more efficient data use also has the potential to improve productivity through better informed and timelier management decisions (Rowe & Banks 2015).

Remote and proximal sensors

Currently there are few remote pasture monitoring technologies that can be utilised by farmers other than the purchase of satellite imagery. Pastures from Space® is a CSIRO initiative that offers services that include pasture growth rates (PGR), feed on offer (FOO), total dry matter (TDM) and Greenness Imagery, based on satellite data and calculated as the Normalised Difference Vegetation Index (NDVI), an index of vegetation 'greenness' and density. While providing a useful index of vegetative state, there are limits to the use of this imagery for intensive pasture management, especially in the case where mixed species are involved, and in the absence of robust and detailed calibration against ground observations and data.

There are also some proximal monitors that observe vegetation greenness, which can serve as a good indicator of pasture and crop health. A number of these sensors have been investigated for dairy pasture systems including ultrasonic and optical plant height sensors (Awty 2009). However, the sensors developed to date are based predominantly on correlations of pasture height to biomass and suffer from the inability to delineate green and senescent material and therefore have limitations in relation to their usefulness for farmers (Trotter et al. 2010).

Sense-T is a Tasmanian initiative that aims to digitise much of the relevant information that could potentially be utilised by land managers in Tasmania. It is a partnership between the University of Tasmania, the CSIRO and the Tasmanian Government, and is funded by the Australian Government. It involves the collection of data from a range of different public and private sources, with a particular focus on wireless sensor systems that are easy to install and operate, collecting data such as

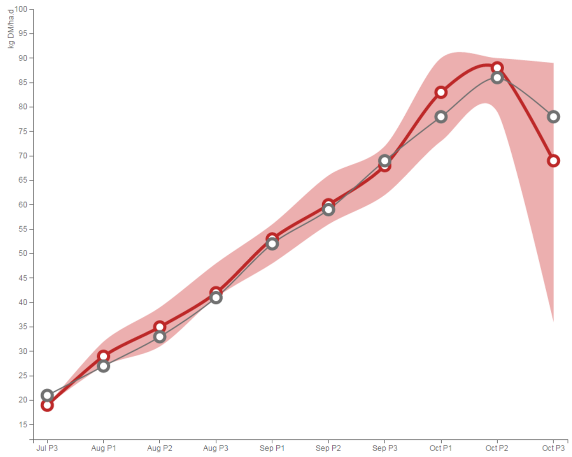

Figure 9: Sense-T Pasture Predictor tool.

Source: University of Tasmania (2015).

soil moisture and temperature at various depths as well as above-ground temperature, relative humidity, solar radiation and leaf wetness. The system saves real-time data into a cloud storage facility, to be aggregated with spatial and historical data.

One of the key achievements of the Dairy and Beef Project component within Sense-T, was the development of the Sense-T Pasture Predictor, an online tool that helps farmers to forecast their future pasture growth and make better decisions in managing their herds, production and costs.

The Pasture Predictor uses data from a range of sources, including current weather conditions and forecasts, rainfall events, past climate records and real-time soil moisture to provide accurate growth forecasts for 30 days and longer-term trends for up to 90 days. Figure 9 above displays forecast pasture growth over the coming 90 days, expressed in terms of kilograms of dry matter per hectare per day (kg DM/ha/d). The red shading indicates percentiles in the 25% to 75% probability range. In the future, Sense-T aims to develop the forecasts for individual properties on a subscription, cost recovery basis (University of Tasmania 2015). While pasture prediction tools are not new, this tool is expected to include improved accuracy and up-to-date data and analytics.

Virtual fences

Constructing and maintaining fences is a major cost for livestock farmers, especially in the pastoral regions. The CSIRO is currently testing a 'virtual fence' in which no physical posts and wires are required. The livestock are confined within boundaries drawn entirely by a GPS system. The fence exists only as computer code. The system consists of a wireless sensor network and the use of cattle neck-collars that emit a sound when the animals approach the virtual 'boundary'. The prototype successfully demonstrated that within one hour the cattle learn to associate the sound signal from their collars with the virtual boundary (Jouven et al. 2012).

Before the system can become commercially available, the durability and robustness of the cattle neck-collars needs to be improved. The potential gains from this technology include reduced labour and costs, better use of pastures, protection of environmentally sensitive areas and the ability to collect information such as production, and health and welfare status of individual livestock.

3.3 Dairy

Digital agricultural applications in the dairy industry had their genesis in individual cow identification systems, as is the case in other livestock industries. The functionality of in-built sensors within the individual ID systems has since developed, as new technologies and more durable battery systems have been developed. Available sensors now provide information about animal activity levels, weight changes, blood composition, milk characteristics and rumen parameters that may assist in management decisions supporting the health, welfare and reproductive management of individual dairy cows. Biometric data are increasingly integrated within financial and supply chain data to form holistic management products (see NLP technologies case study).

An example of an integrated dairy data management system is the MISTRO system developed by Gippsland Herd Improvement which aims to provide the dairy industry with leading edge data collection tools, computer software, and information services, for use on-farm, within service centres, and across the industry.

The MISTRO software system assists dairy farmers to:

- Collect information in the paddock or dairy shed about cows and pastures.
- Maintain accurate records on-farm, herd, and cow management.
- Minimise data entry by interacting electronically with herd recording centres.
- Improve herd and feed management through better record keeping.
- Obtain relevant information from their records that improves decision-making.
- Process their financial transactions and submit tax returns.
- Develop cash flow budgets and financial plans.
- Obtain information from the internet.
- Interact with other dairy farmers on the internet.

MISTRO also provides software solutions for herd improvement centres that provide artificial insemination, merchandising, and herd recording services. Such a system lends itself to future big data applications as a consequence of the range of data collected, including genetic, production and financial information.

Since 2009, Australian dairy farmers have expressed growing interest in robotic or automatic milking systems (AMS) (Dairy Australia Limited 2014a). AMS provide greater flexibility of milking times and milking frequency than conventional milking systems, eliminating the need to milk cows at regular set times. They also require less labour per cow or per litre of milk produced. This allows the operator to shift focus to other areas of on-farm management such as feeding animals, animal health treatments, insemination and calf rearing.

AMS can also milk and monitor each quarter of a cow's udder individually, enabling the operator to assess production and some milk characteristics at an individual quarter level (compared to the whole udder in conventional milking systems). This provides better capacity to manage disease issues such as mastitis before animal health is affected. Milk quality parameters such as conductivity and milk colour can also be measured regularly, as can feed and supplement intake.

Achieving optimal management outcomes for AMS is more challenging under Australian grazing conditions than in Europe where cows are housed indoors most of the time or in a feedlot situation where many of the production parameters can be controlled (Future Dairy 2009).

This is highlighted in the data displayed in Table 2 which provides a comparison of milking machine utilisation and performance in AMS between Australia and Europe. Nevertheless, the systems still provide significant opportunities to improve dairy herd management as a consequence of the objective digital information available from these systems. Table 2 shows potential achievable AMS milking machine utilisation levels of well-managed systems during periods of high utilisation (Future Dairy 2009).

Other management advantages arising from the use of integrated digital information systems (such as activity meters) in dairy production include much more efficient and accurate monitoring of the reproductive status of individual cows, a critical element of herd management. Case studies have estimated that by using activity meters as a back-up to visual cow heat detection saves at least $7000 per year for a 450 cow herd (Dairy Australia Limited 2015).

Other recent systems that have been developed alongside these activity meters are ear tags that measure in-calf heat detection and rumination parameters.

Similar to other livestock industries, the use of walk-over-weighing scales to weigh individual cows has become more common in the dairy industry, with data automatically recorded on the dairy's computer system. Often these systems are used to help provide feeding strategies for individual cows or groups of cows (Dairy Australia Limited 2014b).

3.4 Horticulture

As a sector of agriculture with relatively intensive management systems, high levels of inputs and high value of production per hectare, the horticulture industry is ideally suited to the application of digital technologies to enhance production information and to aid decision-making. The use of digital information and technology in horticulture extends from monitoring and management of inputs such as water and fertilisers (for example fertigation systems controlled by remote telemetry) to monitoring of plant, insect and soil conditions, analysing flowering and fruit setting, through to robotic harvesting and automated grading, packing and chilling systems.

Intensive horticultural production systems, in particular those used for large-scale glasshouse production of flowers and vegetables, have been developed as highly automated facilities utilising

Table 2: Comparsion of AMS performance under Australian and European management systems.

	Typical European system	Australian pasture based system, Camden: peak of season	Australian pasture based system, Camden: annual average
Average milking machine utilisation	90%	80%	67%
Number of milkings/ machine/day	170	150	118
Milk (litres) harvested/ machine/day	2300	2000	1384

Figure 10: Autonomous robot conducting surveillance in an almond farm at Mildura.

Source: The University of Sydney: Faculty of Engineering & Information Technologies (2015).

digital information to control all parts of the production system.

Digital information systems and robotic technologies are being developed for the more extensive horticultural sectors, such as almonds and olives. A key driver of these developments is the relatively high level of labour utilisation in horticulture, combined with high Australian labour costs. This has the potential to render these sectors uneconomic, unless labour costs can be contained or reduced. Robotics creates the potential for this to occur, although technology is still at the developmental stage (Figure 10).

An important difference between the digital information systems that have been developed for the horticulture (and intensive livestock sectors) and the systems that are evolving for broadacre farming is that all the digital information generated in the more intensive sectors tends to be generated and used at the farm level, rather than obtained from public sources or distributed via industry-wide information systems that give rise to privacy and data ownership issues.

Unmanned aerial vehicles

Unmanned aerial vehicles (UAVs) or drones are being used for different applications in cropping and extensive livestock enterprises. These include crop and pasture assessment, and livestock surveillance, and uses have even extended to livestock mustering. For pasture and crop assessment applications, these typically operate by taking large numbers of individual images which are downloaded either directly from a sim card at the completion of the flight or via wireless communications systems during the flight. These images are then processed to correct for various distortions such as topographic relief, lens distortion and camera tilt, and then digitally stitched together to create a single, composite image.

The use of both fixed wing and hover drones is facilitated by integrated software systems (such as Drone Deploy, see Figure 11) that enable the areas which are to be scanned to be first mapped digitally, and the software then automatically retrieves relevant meteorological data and creates an optimal flight path, taking into account wind speed and direction. After the drone is launched, the software then controls the entire flight, while simultaneously 'stitching' together images obtained from each pass over the field, which are downloaded wirelessly during the flight. Within minutes of the drone landing at the completion of a flight, the complete digital image of the field is available on the computer as a colour-coded map which can be used to identify plant stress, greenness, vegetation density and a number of other crop or pasture characteristics.

Improved cameras, including those with hyperspectral capacity, are rapidly increasing the amount of information that can be obtained using these systems. The additional information is being used in systems that are being developed for a number of different applications, including crop disease diagnostics, the analysis of vegetation coverage, and soil moisture status.

The GRDC is currently undertaking a project that is evaluating and testing the use of UAVs in broadacre agriculture businesses in northern NSW. One of the major challenges is ensuring that systems are available that have the processing capacity and wireless transmission reach required to capture the data generated from crop paddocks of the size that are common under Australian conditions, which are many times larger than those that are common in the US corn belt.

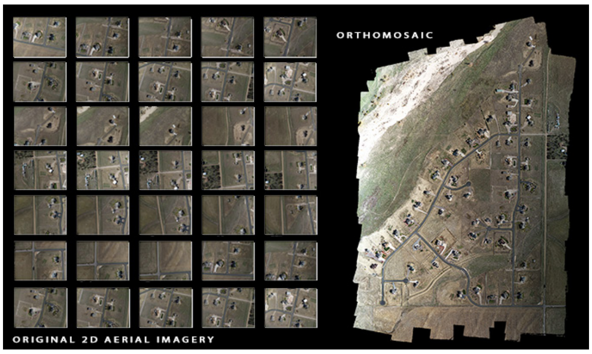

Figure 11: Photogrammetry imagery and a composite image obtained using a UAV.

Source: Drone Deploy (2015).

An alternative is the use of high speed internet connections that can be used to transmit data from the drone to a cloud storage and processing facility, although the poor quality of high speed internet access in rural Australia makes this option largely unfeasible. Even the forthcoming roll out of the NBN satellite network is not expected to assist in this regard, as it will only be suitable for fixed internet access.

Currently, high resolution satellite imagery is considered cheaper and easier to use than UAVs to obtain imagery for assessing biomass and fodder quantity and quality. Nevertheless, in the future cost effective uses for UAVs are likely to be found for remote pastoral stations as the technology develops and the costs reduce.

Satellite imagery

Satellite imagery is expected to remain an important, if not the dominant form of remote imaging for most farm enterprises utilising remote sensing of land condition as a management tool. It is much cheaper than UAV or other technologies, but generally requires ground truthing or UAV calibration in order to verify and quantify crop attributes. The potential exists to calibrate a field against a reference field of similar characteristics – crop type, soil, weather etc. However, ground truthing of the original field is generally required to confirm whether factors such as weeds, disease and plant stress are distorting sensory data.

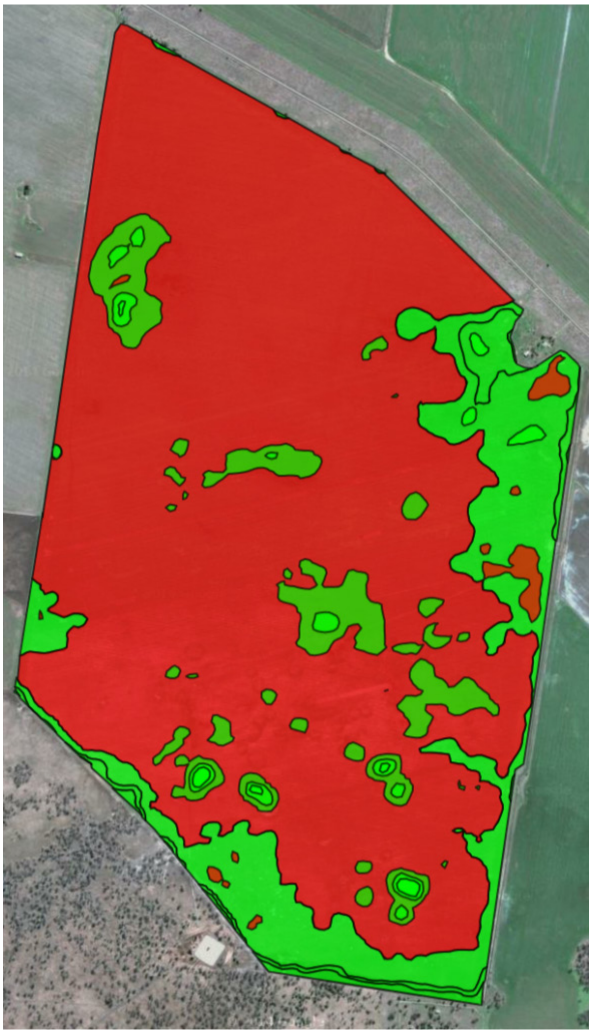

Figure 12: Variable rate map constructed from Satamap data for residual herbicide application.

Source: Boughton (2016).

For some applications, the need for ground truthing is not as critical. For example, mapping the relative measures of biomass across a crop paddock can provide the basis for a variable rate application of herbicide to control a specific problem species. A commercial imagery service provider, Satamap, has been established to sell satellite derived biomass maps of paddocks to farmers (see Figure 12). The farmer is able to use these maps, in combination with knowledge of the growth cycle of particular weed species, to create a variable rate map for use when spraying weeds. The result can achieve quite important savings in herbicide costs, and a reduced future risk of herbicide resistance (Boughton 2016).

3.5 Productivity implications

The available evidence arising from the use of digital technologies and information systems in the agriculture sector is that, while in many instances the systems are still undergoing development and have not reached their full potential, most sectors of agriculture have the potential to secure productivity gains from the adoption of these systems.

The observed gains in the broadacre cropping sector are of the order of 10–15%, with approximately half of these achieved through yield improvements, and half through input cost savings. There is a dilemma associated with these gains in that they are generally not able to be obtained until comprehensive, multi-year datasets are available, and farmers obtain little value from the data during this initial phase.

The scale of potential gains available to the broadacre livestock sector are more varied, and specific to particular production systems and geographic locations. There are already major cost savings being achieved in the pastoral region through the use of remote water monitoring systems, and walk-over drafting systems have been demonstrated to create the potential for a 10% reduction in mustering costs, at a minimum. The potential productivity gains from the use of these technologies in higher rainfall zones is likely to be less as stock monitoring and mustering costs are relatively minor in comparison to those incurred in the pastoral regions.

The ability to monitor pasture growth and availability remotely and objectively in either pastoral or high rainfall production zones has the potential to generate important productivity gains for the broadacre livestock industries, as this would facilitate better pasture and grazing management. Systems to enable this to occur are still in their early development phases, and may be a decade or more away from becoming commercially available. Incorporating digital information about pasture quality and availability with soil moisture, soil nutrient status, climate and livestock data creates the potential for integrated management software platforms for extensive livestock production that are similar to those currently available for cropping, with the potential for significant productivity gains even from available knowledge and technology.

The dairy industry is probably the most advanced in this regard at present, with automated milking and cow management systems currently operating on a proportion of dairy farms and likely to expand in the future. The ability to monitor and manage pastures based on digital information is not yet technically feasible, but once this is possible it will constitute a major advance and open up the potential for important productivity gains.

Further into the future the potential arises for the development of autonomous farm equipment that could carry out most routine management activities including cultivation, spraying, seeding, fertilising, harvesting, mustering and drafting. Autonomous tractors are currently being trialled for a number of different crops, and the cotton industry has already introduced harvesters that constantly stream machine and production data to cloud-based storage facilities, and which can subsequently be used to guide different management decisions. The step from current systems to fully autonomous, or remotely-controlled machinery operations is not large, and already has a precedent in the mining industry.

The ability to change broadacre farm management from paddock or herd averages to management at the square metre or individual animal level brings the promise of important productivity gains, even with the use of existing production knowledge. Digital information systems are a critical part of that transition.

Technologies are generally available to enable these changes to occur, or are feasible given existing technologies operating in agriculture or other sectors. This transition will bring with it the need for a new generation of technologically savvy agricultural managers, an agricultural service sector with new knowledge and skills, and telecommunications and related infrastructure to enable these systems to operate throughout rural Australia.

3.6 Compliance and supply chain implications

Digital information systems are already widely used within supply chains after the farm gate. The development of on-farm digital systems that are integrated with post-farm systems provide opportunities for cost savings.

In post-farm supply chains, pre-shipment inspection data, quality analysis of products and supply chain operational data are already well developed and can be expected to become increasingly sophisticated. The greater control afforded post-farmgate has already had a discernible impact on wastage.

A good example of this is the post-farm supply chain for horticultural exports. Digitised pre-shipment inspection data has, in specific cases, largely eradicated the rejection of horticultural produce shipments into China, to the extent that the market is rapidly incorporating such inspection data into its standard operating procedures for exporting fruit. This includes a chemical analysis of fruit and assessment of physical qualities such as firmness maturity, temperature, weight etc against vendor requirements. The success of the pre-shipment assessment and data collection is such that many insurers of Australian horticultural exports now require the grower to provide this pre-shipment data as a condition of their insurance cover (Hortus Technical Services 2016).

It is expected that insurers may soon require the full life cycle of production input data. Irrespective of contemporary requisites, the insurance market would be expected to move toward data transparency as insurer risk is alleviated.

Supermarkets are also beginning to build supply chain monitoring capabilities into their business models. ALDI enforces its own specifications for sustainable farming which effectively requires input data from producers. The seafood supply chain control is particularly notable. Suppliers must provide information across the value chain to ensure traceability and compliance with accepted aquaculture and wild catch specifications.

ALDI recently partnered with Sedex (Supplier Ethical Data Exchange) which operates a platform through which suppliers can opt to share data pertaining to ethical practices in labour standards, health and safety, environment and business ethics with customers (Sedex 2015).

The expected benefits include improved supply chain risk management as well as reputational benefits. It is expected that consumer preference for sustainable practices and efficiency gains will push suppliers and vendors alike into stricter supply chain regulations and more transparency.

Digital agriculture and data analysis is also being employed by the Queensland Government to reduce nutrient run-off into the Great Barrier Reef Marine Park from sugarcane operations. A crucial component of this initiative is encouraging farmers to comply with Smartcane BMP (Best Management Practices). The aim of this approach is to showcase productivity and input efficiency delivered through Smartcane BMP to incentivise uptake by growers. By implementing these practices farmers reduce nutrient run-off and associated damage to the reef.

Currently, compliance with the BMP program is voluntary. However, recent announcements made by Canegrowers Australia suggest that unaccredited growers will face increased scrutiny by the Queensland Government (Sparkes 2015).

Smartcane BMP ensures that farmers comply with existing regulations. The Queensland Government summarises the obligations for cane farmers in the Wet Tropics, Burdekin and Mackay-Whitsundays regions as follows:

- keep records of their use of fertilisers and agricultural chemicals
- undertake soil tests
- use the results of soil tests, and the regulated method, to calculate nutrient requirements and apply no more than the optimum amount of fertiliser (nitrogen and phosphorus)

- follow product label instructions when using agricultural chemicals such as herbicides and insecticides
- follow specific controls when using herbicide products containing atrazine, ametryn, hexazinone and diuron (including prescribed user training qualifications, spray-droplet size restrictions, no-spray windows, and restrictions on use prior to rainfall and near waterbodies). (Queensland Government 2016)

The program employs NutriCalc, an online nutrient management tool incorporated into the BMP program. The tool itself calculates nutrient requirements from soil tests, benchmarks, analyses nutrient trend data against climatic events as well as functioning as a management tool for farmers to record and monitor costs (Schroeder et al. 2014).

Data and information obtained under the BMP program will be used to refine nutrient prescriptions, farmer reporting and ultimately the direction of the project. It is hoped that ongoing reporting and collection of data will deliver better outcomes and become embedded in farming operations (Canegrowers Australia 2013).

4. The market for farm data storage and analysis

As is the case in any other economic sector where digital information and management systems have developed, the emergence of digital agriculture has brought with it a support industry providing a variety of services. These services include software development, data storage and retrieval services, data integration services, digital information system development and implementation, data analytics services and related training and advisory services. The digital agriculture service industry is in its infancy in Australia and its structure and likely development is as yet uncertain, although the history and development of the digital agriculture service sector in the US provides some indications of likely developments in Australia.

The initial impetus for the development of digital information systems in the cropping sector in the US in the late 1980s was the development of variable rate fertiliser machinery. These initially relied on manually-prepared maps of soil conditions at a sub-field level based on gridded soil testing. As GPS became available in the early 1990s they were adopted for both variable rate fertiliser and seeding equipment, and also in harvesters to create yield maps. As the volume of data and information increased, software platforms were developed to help farmers and their advisors manage and store it.

In the US, initial developments in the provision of digital services for crop farmers involved either input suppliers (seed and chemical retailers), or software companies which developed products that removed some of the administration and paperwork from the services provided by these companies. A typical software application enabled a retail crop advisor to visit a farm and to map and plan a cropping program with a farmer client. This involved the selection and mapping of fields to be cropped, the selection of seed varieties to be purchased and used, the selection of soil treatments and chemicals, and decisions about the amount of fertiliser that would be applied, based on soil test results. The software systems essentially facilitated the decision-making processes, automated the ordering of required inputs, and also provided access to technical information about specific inputs.

As variable rate seeding and fertiliser applications became more common, digital control systems were developed, some of which were specific to a particular machinery brand, and others which were more generic and could be used with a number of different brands. These could be used to define different zones within a field, and to vary seeding and fertiliser applications rates for each zone. At the same time, the capacity of harvesters to record and map crop yields was further developed, and machinery manufacturers developed proprietary digital information systems, which meant that yield maps produced by one harvester company were incompatible with those produced by another, and each required different software systems. Machinery manufacturers essentially developed digital information systems initially as a loyalty service, which had the objective of ‘locking’ farmers into one specific brand of machinery.

A number of factors have changed this situation over the past five years. Farmers and their advisors were unhappy being locked into a single machinery brand in order to make use of digital information generated on their farm. They commonly buy one brand of harvester, a different brand of tractor, and a different brand of seeder. US corn farmers also typically have external contractors apply in-crop fertilisers. Proprietary digital information systems imposed major limitations on the use of digital information for different farm operations.

A competitive market also developed in the provision of software platforms, with independent providers developing comprehensive systems which incorporated a variety of mapping and other functions that extended well beyond machinery operations. It became an increasing challenge for machinery companies to incorporate all the functionality that farmers were demanding into their systems.

Technological developments also created opportunities for new players in the digital agriculture space. For example, a US company called Farmobile has developed a passive uplink connection (PUC). It is designed to be a 'neutral data pipe' that collects and centralises data from multiple farm machinery brands and models using the ISO11783 communication protocol. Data can be shared between application programming interfaces (APIs) and made accessible to agronomists or for analysis at the farmer's discretion (Farmobile 2015).

The development of a competitive market for digital agriculture software platforms and applications has been further enhanced by initiatives such as the Open Agriculture Data Alliance (OADA). The Open Agriculture Data Alliance is an initiative by a group of researchers based at Purdue University in Indiana, who are promoting the concept of making all agricultural data 'open source' so that it can be more easily integrated, and so that a competitive market can develop for data application software and smartphone apps.

The motivation for OADA came from the frustration felt by farmers who had multiple sources of data from a range of different applications and were unable to integrate that data into a single useful format that could be used for different purposes. The objective is to provide open source software from competitive suppliers that can be used by farm service providers for a range of different applications.

OADA is developing secure data exchange protocols through APIs and developer libraries. It allows for datasets uploaded from various on-farm sources to communicate, synchronise and be accessed within the farmer's chosen software platform or data storage facility (cloud). The farmer

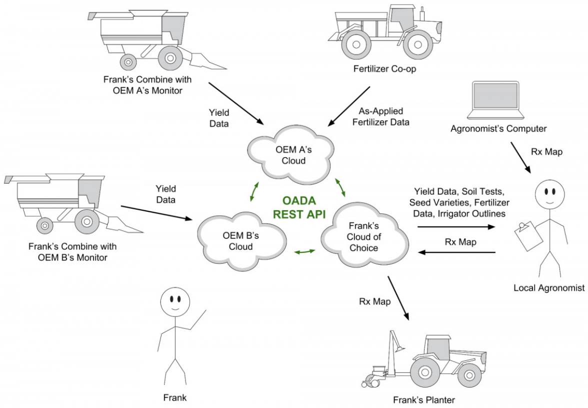

Figure 13: The farm data ecosystem.

Source: Open Agriculture Data Alliance (2014).

can then choose to allow an agronomist or any other outside party access to that data.

They believe the data should belong to the farmer to control as they see fit, and that by having open access arrangements and development tools, this will provide farmers a choice in who they can usefully grant access to their data. They also believe that there should be arrangements associated with levels of 'trust' which enable farmers to decide who has access to what level of data.

OADA is making some progress with major machinery manufacturers and agrichemical companies, who have committed to participate in the alliance and make data available in open source format (Open Agriculture Data Alliance 2014). The 'open data' concept is based on the premise that the data produced by each different machine/technology is able to be accessed by software tools and converted from one form to another – not necessarily that they are in a standard format. Some challenges arise because conversions from one data format to another are not usually 'loss-less' and can result in information being lost in the translation.

Suppliers have begun to build interoperability into their business models. For example, SST Software provides widely used software for agronomists and retailers based on a range of data types including yield data from seed suppliers across industry, weather and soils data. Data utilised by the SST

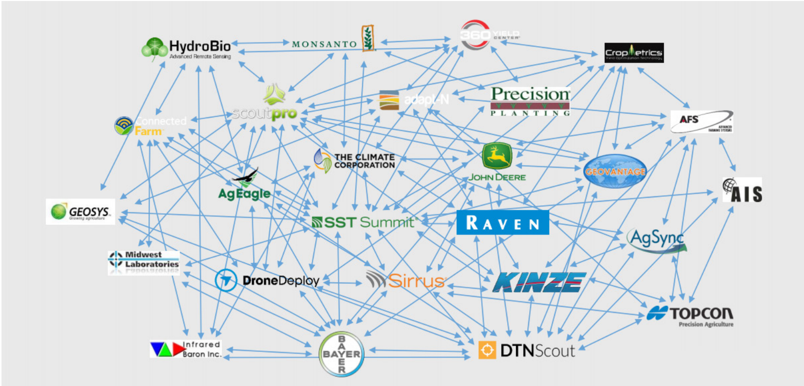

Figure 14: A map of the interoperability network that has developed amongst digital agriculture systems and platforms in the US.

Source: SST Software (2015).

Software is stored on a central hub referred to as the agX platform. The platform involves standardised data protocols, a 'store' of competing software applications (APIs), data storage and retrieval capacity, and permission-based data sharing capacity to enable data to be exchanged between farmers, their advisors, and machinery and equipment suppliers (agX 2015).

From the perspective of software companies like SST Software, interoperability achieved through either APIs or a standardised central repository provides a pan-industry data repository with potential to partner with complementary service providers. At the time of writing this report agX is building a central store of agX-compliant applications and services. The hope is that such a platform will facilitate cross company collaboration. For example, modules owned and operated by water modelling companies would generally be complementary with nutrient modules of different companies. These in turn could be utilised by or combined by a third party with weather and soil data. Functional interoperability would allow smaller companies to compete in niche corners of an integrated analytics package delivered to a grower (agX 2015).

On evidence from interviews with farmers and industry professionals it is unrealistic to expect most farmers to spend time selecting service providers piecemeal as part of wider application of big data. Rather, it would be expected that the majority of users would be agronomists and retailers capable of building a tractor-ready product (for example a variable rate planting prescription) using data sourced from multiple service providers.

Naturally, open standards facilitate competition downstream of equipment manufactures and data collection products. Without transferable datasets, companies that control the initial creation could potentially monopolise downstream data services. Encouragingly, a number of large agribusiness suppliers including the Climate Corporation are embracing open standards. Larger data silos are inherently more valuable where data aggregation is required.

It is the belief of many within the industry that data storage will gravitate toward either open or universal standards, essentially reducing the number of data silos to one. It remains to be seen whether this will be an effective strategy.

With sufficient interoperability, datasets originating from different sources can be aggregated and used for benchmarking and research purposes at the behest of the farmers. The issue of ownership is discussed further in Chapter 5. It is generally agreed that farmers or their contractors own the data generated on-farm and will be assumed as such for the time being. Nevertheless, issues of privacy and appropriating value need to be addressed to ensure easy proliferation of data to key stakeholders.

Open source philosophy for data diminishes the opportunity for profiting from basic storage and retrieval services. agX anticipates that compliant data collectors may be able to sell their data on the platform to those wishing to incorporate wider datasets. It is unknown how large the market for third-party data will become. It is expected that most of the value will be derived from downstream products including algorithms underpinning the analytics and farm management products.

If effect, what has emerged in the US is actually three interconnected markets. The first is the market for machinery control and monitoring systems, in which the participants are the major machinery manufacturers, plus 'independent' suppliers such as Trimble, Raven and AgLeader. The second is the market for data storage and retrieval services, in which the participants are major equipment suppliers such as John Deere with the myJohnDeere platform, the agX platform supported by SST Software, and a large number of other cloud storage and retrieval services offered by major companies such as Amazon and Apple, or smaller regional farmer cooperatives or crop advisory groups. The third market is the market for APIs – computer programs and applications on smartphones or tablet computers that can be used to retrieve, synchronise, coordinate and utilise data for the purposes of farm operations or as a guide to decision-making.

The adoption of open source data or open access data platforms has facilitated the development of these markets, and has also enabled suppliers to generate revenue from value-adding services, rather than simply providing them as an extra service to secure customer loyalty.

Appropriating value to the farmer

While the emergence of competitive service providers has facilitated the rapid development of a user-pays digital agriculture service in the US corn industry, which farmers are now paying to access, one of the most common issues raised by farmers is whether the data they generate has the potential to deliver any value beyond its use for farm decision-making. Farmers have been told for some time that their farm data is valuable and potentially useful to governments, agricultural technology providers and researchers, but as yet have not been able to realise any direct revenue from those seeking access to the data.

The most direct way to appropriate value is simply for users to pay farmers (data owners) for access to their data files. One avenue suggested would be a cooperative agreement where third parties would purchase a collective set of farm data or pay an amount for a specific set of farm data provided by a data cooperative. While attractive from a farmer's perspective, support for this arrangement appears to be diminishing. Data markets are moving toward a model where data warehousing is open source and the value for farmers is derived from algorithms and associated downstream products.

This doesn't necessarily preclude the emergence of a data cooperative to warehouse data. As the owners of data, farmers could choose to share data only with the cooperative which would then grant third parties access to the 'master' dataset of farm data. However, the ability to control data would be contingent on farmers not sharing similar data with other storage platforms. At the same time withholding data from an agricultural technology provider (ATP) may reduce some of the functionality of the ATP equipment or services as per licensing agreements (see Section 5.3 below). It is almost certain that most individual farm data would be provided to ATPs. The exclusivity of such a cooperative dataset relies on a large proportion of farmers not allowing the ATPs to share aggregated data outside the cooperative arrangement. It is not certain that this could be effectively prevented. Even if it was possible to establish a fence around an industry-wide dataset, it is unlikely to be desirable. Open source data removes financial barriers to entry and thereby facilitates competition between downstream software providers delivering products and services to farmers, and from the use of which farmers ultimately benefit.

The simplest and seemingly most likely scenario is farmers forgoing monetary payment for data and indirectly receiving some of the benefits of industry research/services. This arrangement would have the advantage of encouraging research as the cost of the data's value would be 'invested' by farmers who would expect to share in the benefits. Benefits could take the form of research dissemination, additional services or simply improved data quality underpinning service providers. Competition within the private sector would also be crucial to driving product improvement for the farmer. The quality of services would be expected to increase iteratively as providers seek new customers.

Reflecting this approach, the Sense-T project operating in Tasmania has been 'established on the premise that we all benefit by sharing data, so long as privacy is protected.' For example, the Sense-T Water Management program uses sensors to improve water management in the South Esk and Ringarooma catchments. It hopes that:

> [B]y providing irrigators with real-time information about river flows, weather and water quality, better decisions about water management can be made for the benefit of farmers, regulators and the environment.
>
> (University of Tasmania 2015)

From interviews with farmers in Australia and industry representatives in the US, it is apparent that attitudes toward data sharing vary significantly among farmers. A large portion are content to share with industry stakeholders if they can see wider benefit. Many more seemed relaxed about privacy and trade secret issues but expressed a wish to receive payment or at least some form of return from provision of their data. A small portion expressed extreme reluctance toward giving up their data.

Purchases of properties with historical data

Historical data for a property has a much greater value for the purchaser of the property compared to data scientists looking to aggregate the data for the purposes of product improvement. Data can provide the property buyer with immediate knowledge pertaining to farm characteristics and guidance on optimal practice. The same dataset amongst many may not provide a large benefit to ATPs and software developers. Value in this case is defined by use rather than the data itself. Chapter 5 discusses methods for quarantining usage of data and by extension its value.

It would be expected that historical data would be bundled with the physical real estate. From the perspective of the seller, transferring electronic records to the buyer would require little effort or expenditure. Provided the data contained no trade secrets or sensitive information, a competitive marketplace should see the price of data approach zero. In a more likely scenario with limited sellers, particularly within some enterprise categories, there is the potential to put a price on data transfer, which would be an amount less than the expected cost of acquiring that data from later operations.

The Australian market

The relative immaturity of the Australian digital agriculture service market makes it difficult to anticipate how this market may develop, although there are a number of factors that dictate probable developments.

Australian farmers use farm machinery that has largely been designed and developed overseas, and it is highly unlikely that overseas manufacturers will develop unique systems for the Australian market, given its relatively small size. Consequently, the machinery-related systems and products that will be available for use by Australian farmers are likely to be the same as, or only marginally adapted from existing products and services currently being utilised by US farmers. This means that it is likely that the same open source and open-access protocols will apply, creating the opportunity for a competitive market for farm data storage and software applications, and making it likely that interoperability between different systems and platforms will be the norm.

There is also a strong likelihood that software and applications that have been developed in the US market by organisations that are independent of the major machinery firms will also be adapted for the Australian market, and made available to farmers and advisors. Current examples include Agworld and SST Software (see Figure 15, over page), both of which have already established Australian operations and have products that are available for a range of different uses associated with both cropping and livestock production.

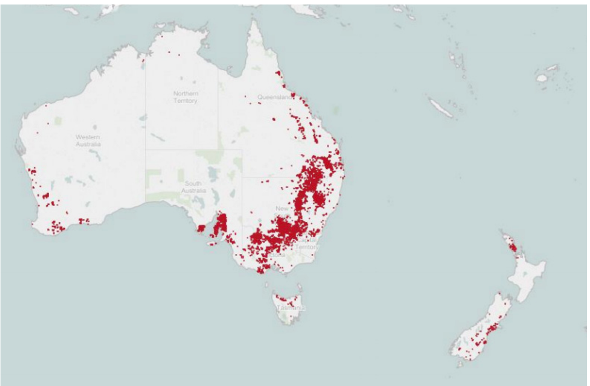

Figure 15: Australian and New Zealand croplands mapped using SST Software.

Source: SST Software (2015).

SST Software products are currently used by Australian crop advisors employed by several large companies supplying inputs and advisory services to the Australian grains industry.

Independent suppliers of machinery consoles, such as Trimble and Raven, also have a presence in Australia, and are used in conjunction with a number of different machinery brands.

What is less certain about the future Australian digital agriculture market is whether it is large enough, and has the underlying infrastructure and public data stores that have been critical to the development of this market in the US. It is very obvious in talking to those involved in the digital agriculture market in the US that the availability of very detailed and extensive climatic data from a dense weather radar and reporting station network, in combination with detailed soil maps and datasets published by the United States Department of Agriculture (USDA), plus a range of publicly-available GPS and cadastral data services has facilitated the development of the digital agriculture service sector in the US (see Figure 16).

Digital agriculture in the US is also reliant on very intensive soil testing (at rates of samples per acre, rather than acres per sample as is the case in Australia) and relatively inexpensive soil testing costs compared to Australia. (A standard

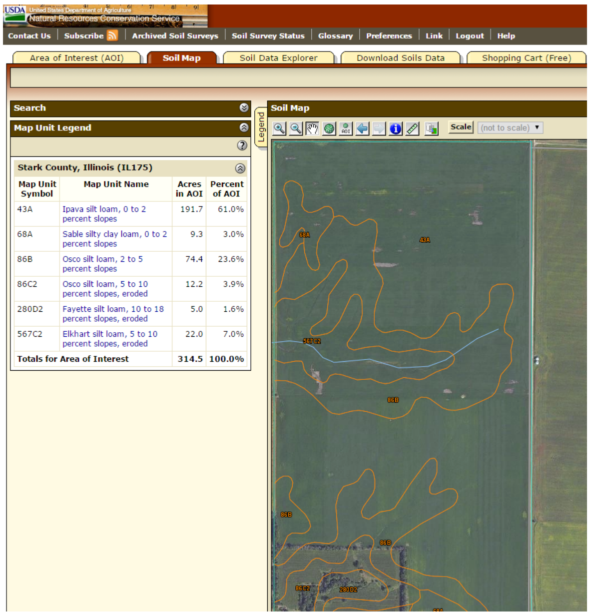

Figure 16: An example of the 1:25000 soil maps and data accessible at the individual field level from the USDA.

Source: USDA (2015).

soil nutrient analysis in the US costs of the order of US$8–10 per sample, compared to costs in Australia of between $60 and $100 per sample.)

In the absence of this detailed information, the process of developing zone maps for VRA seeders or spreaders in Australia will depend on gridded soil test data at a level of intensity that is far lower than that available in the US or farmers' or crop advisors' knowledge about the specific soil types present in a particular paddock. Available climatic data may have to be extrapolated from the nearest weather stations which may be up to 100 kilometres distant from the specific paddock. This set of circumstances clearly imposes limitations on the potential utility of digital agricultural systems, unless initiatives can be implemented to overcome some of these issues.

While it is tempting to think that the Australian cropping sector might simply be able to 'ride on the back' of digital agricultural developments that have already occurred in the US, there are some very significant limitations in Australia that mean that this may not be the case.

The most advanced cropping products tend to be targeted at US corn and soybean produces. This reflects market scale and higher revenue per hectare in comparison to other markets such as Australia. Nevertheless, Climate Corporation has flagged expansion of its products into wheat and canola and is launching platforms in Canada and Brazil (Stern 2015). Modifying products for other crops is non-trivial. For example, soil nitrogen levels depend partially on last year's crop residue. Climate Corporation uses extensive data on nitrogen and carbon retention of corn and soybean residue to estimate soil nitrogen levels (Climate Corporation 2015). For commodities more common in Australia, there may not be comparable repositories of data and field tests to underpin nutrient models. Higher costs per soil test and other data inputs further erode potential profitability within Australia. Nevertheless, digital agriculture developments in the US represent at the very least, proof of concept if not always transferable business models.

In the case of the livestock industries, there have been digital systems developed in the US for the intensive sectors such as pork, poultry, dairy and beef feedlots. These systems utilise data largely generated inside the farm gate, and do not need to access public soil and climatic data. The inputs utilised in intensive livestock production systems are also largely controlled and measured, which greatly reduces the complexity of data needs and analysis. Many of these systems are already in use in Australia, or the Australian businesses have developed proprietary digital information systems which have been used for some time.

There has not been the same degree of development of digital information systems for extensive livestock production systems. Those systems that are available tend to operate as an electronic paddock diary, enabling users to record changes in livestock numbers, grazing arrangements and animal weights. These systems have not been developed to the point where they are used to determine the need for specific management changes, or to project the outcome of particular management decisions. The National Livestock Identification System (NLIS) in Australia provides an important base data infrastructure that may play a facilitative role in the development of digital information systems in the extensive livestock industries in the future.

5. Agricultural data and privacy

For many farmers, while the potential opportunity to achieve productivity gains through the adoption of digital agriculture is attractive, there are nagging concerns about making available detailed farm production and other data on electronic platforms that are accessible to unknown third parties, and which may be used for purposes over which the original provider of the data has no control. The following section of the report analyses these issues by examining the current legal framework, by considering some relevant international models, and by examining a number of case studies.

5.1 Legal framework relevant to agricultural data

There are potentially three areas of Australian law that may be relevant to the providers and holders of digital information generated from Australian farms. These are the legal frameworks associated with:

1. Confidentiality and trade secrets
2. *The Australian Privacy Act*
3. the guidelines and legislation under which Australian statistical agencies operate.

Confidentiality

The person who has generated data and who is the owner of that data (in this instance generally assumed to be the farmer) can legally apply conditions of use and disclosure on those who are allowed to access the data. This is in the form of a legally-binding contract, which is enforceable through the courts should that contract be breached. This applies in general to information owned by an individual, and this arrangement is generally given effect via a confidentiality agreement. IP Australia provides the following overview on the application of confidentiality agreements:

> Confidentiality agreements can be made with anyone (employees, business partners, business associates, research academics and so on) whom you wish to impose an obligation of confidence on, regarding the use and disclosure of your confidential information.
>
> (IP Australia 2013)

Farmers or data owners who feel data contains information about the farm business that they do not wish to disclose can request it be kept confidential via confidentiality clauses in a contract. Even in the event there has not been a confidentiality agreement negotiated, under Australian law there is a default obligation to maintain confidentiality.

The Australian Law Reform Commission Report 108 provides an explanation for Common Law and equitable duties of confidence. In a section detailing obligations of confidence, it describes circumstances where confidentiality obligations may arise through equity and without a prior contractual agreement.

> **15.126** A contractual obligation of confidence can arise from express terms in a contract, but also by implication. The nature of the obligation will depend on the terms of the contract. Remedies for threatened and actual breach of the contractual obligations to maintain confidence include injunctions and damages.
>
> **15.127** An equitable obligation of confidence can arise where the formalities for the formation of a contract are not present. The obligation arises where information with the necessary quality of confidence is imparted in circumstances importing an obligation of confidence. Such circumstances will exist where the information is imparted on the understanding that it is to be treated by the confidant on a limited basis, or where the confidant ought to have realised that in all the circumstances the information was to be treated in such a way. Breach of the obligation occurs where there is an unauthorised use,

> not only where there is unauthorised disclosure, of the information.
>
> **15.128** Unlike the position in contract, where loss is the basis of a claim for damages, the plaintiff in a suit for breach of the equitable obligation does not need to show any damage. Remedies for breach of the equitable obligation include compensation or an account of profits, an injunction and a declaration.
>
> (Australian Law Reform Commission 2008)

Crucially, obligations of confidence apply to both the unauthorised use as well as disclosure of information.

This means that in the absence of an agreement explicitly waiving the rights of the owner of farm data to confidentiality, there is a default confidentiality obligation on the provider of the software platform or data storage service to maintain the confidentiality of the data, and to not make it available to a third party or use it for any purposes which the data owner does not agree with.

In effect, however, all users of farm software platforms and data storage services (and any computer software and cloud storage services) generally sign a user agreement which waives some or all of the confidentiality requirements associated with the data that is made available by the user.

Trade secrets

A related area of the law that may be relevant to privacy issues associated with farm data is the legal framework for the protection of what are termed ‘trade secrets’. There are four basic forms of intellectual property (IP) that are recognised under law. These are patents, copyrights, trademarks and trade secrets. Of the four, trade secrets is the only form that could be relevant to farm data (Janzen 2015a).

IP Australia describes trade secrets as follows:

> A trade secret is both a type of IP and a strategy for protecting your IP. It can provide effective protection for some technologies, proprietary knowledge (know-how), confidential information and other forms of IP.
>
> A trade secret is appropriate when it’s difficult to copy a product. This may include the construction or formulation of the product or the process of manufacturing the product when reverse engineering is unlikely.
>
> The best known example of a trade secret is that of the Coca-Cola recipe. The company has used trade secrets to keep its formula from becoming public over a period of decades. It never applied for patent protection, so it was never required to disclose the formula. One disadvantage is that trade secrets do not provide any legal security against an independent competitor inventing an identical object. (IP Australia 2013)

Data collected on-farm would assist in developing improved processes, some of which may already be implemented by individual farmers and considered a trade secret. For example, a farmer who believes they have identified an optimal summer legume for their particular location through iterative seasonal experimentation may not wish to have this information made available to other farmers in the same region who have not expended the same effort.

This information might be considered a trade secret and the farmer could therefore seek to have it remain confidential. However, whether farm information constitutes and remains a ‘trade secret’ will be influenced by factors such as:

- the extent to which the information is known by others
- the extent of measures taken by the farmer to guard the secrecy of the information
- the value of the information to the farmer and potential competitors
- the amount of effort or money expended by the farmer in developing the information
- the ease or difficulty with which the information could properly be acquired or duplicated by others.

It is probably reasonable to conclude that, except in very specific situations, it is highly unlikely that farm data would be considered to constitute a trade secret, and would therefore automatically be subject to protection and confidentiality provisions on that basis. It is also worth noting that even in limited situations where this might be considered to apply, it would be likely that this protection would diminish over time if the information or the practice became more widely known or adopted.

Australian Privacy Act

A second area of law that may be considered to be applicable in relation to the protection of farm data is the *Australian Privacy Act 1988* (Privacy Act).

The Privacy Act regulates how personal information is handled. The Privacy Act defines personal information as, 'information or an opinion, whether true or not, and whether recorded in a material form or not, about an identified individual, or an individual who is reasonably identifiable.'

Common examples are an individual's name, signature, address, telephone number, date of birth, medical records, bank account details and commentary or opinion about a person (Commonwealth of Australia 2015a).

The Privacy Act incorporates a series of legally binding principles – Australian Privacy Principles (APPs) – which regulate the handling of personal information by the Australian Government, the ACT Government and private sector organisations. The Privacy Act requires that persons whose personal information is being collected have a right to:

- know why personal information is being collected, how it will be used and who it will be disclosed to
- have the option of not being identified
- ask for access to their personal information
- ask to stop receiving unwanted direct marketing
- ask that personal information that is incorrect be corrected
- make a complaint about an entity covered by the Privacy Act, if it is considered that personal information has been mishandled.

The common view expressed in interviews with lawyers was that the Privacy Act would have little relevance to farm data, as most of the data involved would not be considered to be personal information. Nevertheless, for some data, individual farmers owning the data may be able to assert protection under the Privacy Act.

Statistical agencies

A third area of law that may have some relevance in relation to farm data that is provided to service providers is the law that governs the collection and use of information by the Australian Government for statistical purposes. Conceivably, in the event that digital agricultural applications became widely used by farmers, the Australian Bureau of Statistics (ABS) might decide to require digital agriculture service providers to release information to the ABS that could subsequently be used to produce official statistics. For example, in the event that digital agricultural applications were widely used by crop farmers, the information held by those service providers detailing the area planted to crops by farmers could provide a very useful source of information about changes in national crop production.

The *Census and Statistics Act 1905* governs the collection national statistics. Section 12 paragraph (2) of the Act is of particular relevance to data privacy. The paragraph dictates that the release of information which can be reasonably used to identify an individual determine person or organisation is prohibited, 'The results… shall not be published or disseminated in a manner that is likely to enable the identification of a particular person or organisation.' (Commonwealth of Australia 2006)

Concerns about privacy in relation to national statistics databases are not new, nor limited to agricultural data. The ABS has collected data from households and business long before the era of big data and routinely uses various measures to prevent the identification of individuals. Additionally the ABS has internal administrative arrangements in place to ensure that employees cannot access both the personal identifiers and the content of statistical information that it requires individuals or businesses to provide. As the agency explains:

> The ABS separates identifying variables from content variables as part of its suite of strategies to protect the identities of individuals and organisations in datasets. This means that no-one can see the identifying or demographic information, used to identify which records relate to the same person or organisation (eg name, address, date of birth), in conjunction with the content

> data (eg clinical information, benefit information, company profits). Instead, staff can see only the information they need to do the linking or analysis. So, rather than someone being able to see that John Smith has a rare medical condition, or the profits earned by Company X, the person doing the linking sees only the information needed to do the linking (eg John Smith's name and address) and the analyst just sees a record, with no identifying information, showing that a person has a rare medical condition together with any other variables needed for analysis (eg broad age group, sex).
>
> (Australian Bureau of Statistics 2013)

In conclusion, while the development of digital agriculture may provide government statistical agencies with new and administratively efficient opportunities to collect data for statistical purposes, there is no obvious reason for farmers using digital agriculture services to be concerned that they are exposed to additional risks in relation to the misuse of their farm data by government statistical agencies.

5.2 International digital agriculture standards

Unsurprisingly, farmers in overseas locations where digital agricultural services are more developed than is the case in Australia have raised concerns about data ownership rights and privacy, and service providers have taken steps to give greater reassurance to users about the protection that is available for their farm information.

Digital agriculture service providers typically address privacy and other issues arising from national legislation through written contracts, which users are required to agree to before using the software. The requirement to agree to the contract or terms of use prior to using the software is not confined to digital agriculture applications, and in fact is almost ubiquitous for any software or computer applications. In effect, most of these contracts or terms of use require the user to acknowledge a set of conditions, which usually means that the user agrees to waive specific legal rights in return for being able to use the software. Alternatively, the terms of use may provide superficial reassurance about the privacy or use of the information, but may also bury exclusions deep in the document which in effect give free reign to the software providers (ATPs) to use the data in many different ways, including via the sale or transfer of the data to a third party.

The US and New Zealand agriculture sectors in particular have taken steps to clarify data ownership rights, via the introduction of voluntary industry standards. The aim of both standards is to establish a common understanding between users and service providers about data ownership and protection, with the hope that this approach will prevent or discourage misuse of farm data, while avoiding the heavy hand of regulation and its likely negative impact on innovation.

Privacy and security principles for farm data (US)

The US Farm Bureau's Privacy and Security Principles for Farm Data are a set principles to be upheld in contracts between compliant organisations and farmers. The specific standards contained in the US principles are as follows:

> **Education:** Grower education is valuable to ensure clarity between all parties and stakeholders. Grower organizations and industry should work to develop programs, which help to create educated customers who understand their rights and responsibilities. ATPs should strive to draft contracts using simple, easy to understand language.
>
> **Ownership:** We believe farmers own information generated on their farming operations. However, it is the responsibility of the farmer to agree upon data use and sharing with the other stakeholders with an economic interest, such as the tenant, landowner, cooperative, owner of the precision agriculture system hardware, and/or ATP etc. The farmer contracting with the ATP is responsible for ensuring that only the data they own or have permission to use is included in the account with the ATP.
>
> **Collection, Access and Control:** An ATP's collection, access and use of farm data should be granted only with the affirmative and explicit consent of the farmer. This will be by contract agreements, whether signed or digital.
>
> **Notice:** Farmers must be notified that their data is being collected and about how the farm data will be disclosed and used. This notice must be provided in an easily located and readily accessible format.
>
> **Transparency and Consistency:** ATPs shall notify farmers about the purposes for which they collect and use farm data. They should provide information about

how farmers can contact the ATP with any inquiries or complaints, the types of third parties to which they disclose the data and the choices the ATP offers for limiting its use and disclosure.

An ATP's principles, policies and practices should be transparent and fully consistent with the terms and conditions in their legal contracts. An ATP will not change the customer's contract without his or her agreement.

Choice: ATPs should explain the effects and abilities of a farmer's decision to opt in, opt out or disable the availability of services and features offered by the ATP. If multiple options are offered, farmers should be able to choose some, all, or none of the options offered. ATPs should provide farmers with a clear understanding of what services and features may or may not be enabled when they make certain choices.

Portability: Within the context of the agreement and retention policy, farmers should be able to retrieve their data for storage or use in other systems, with the exception of the data that has been made anonymous or aggregated and is no longer specifically identifiable. Non-anonymized or non-aggregated data should be easy for farmers to receive their data back at their discretion.

Terms and Definitions: Farmers should know with whom they are contracting if the ATP contract involves sharing with third parties, partners, business partners, ATP partners, or affiliates. ATPs should clearly explain the following definitions in a consistent manner in all of their respective agreements: (1) farm data; (2) third party; (3) partner; (4) business partner; (5) ATP partners; (6) affiliate; (7) data account holder; (8) original customer data. If these definitions are not used, ATPs should define each alternative term in the contract and privacy policy. ATPs should strive to use clear language for their terms, conditions and agreements.

Disclosure, Use and Sale Limitation: An ATP will not sell and/or disclose non-aggregated farm data to a third party without first securing a legally binding commitment to be bound by the same terms and conditions as the ATP has with the farmer. Farmers must be notified if such a sale is going to take place and have the option to opt out or have their data removed prior to that sale. An ATP will not share or disclose original farm data with a third party in any manner that is inconsistent with the contract with the farmer. If the agreement with the third party is not the same as the agreement with the ATP, farmers must be presented with the third party's terms for agreement or rejection.

Data Retention and Availability: Each ATP should provide for the removal, secure destruction and return of original farm data from the farmer's account upon the request of the farmer or after a pre-agreed period of time. The ATP should include a requirement that farmers have access to the data that an ATP holds during that data retention period. ATPs should document personally identifiable data retention and availability policies and disposal procedures, and specify requirements of data under policies and procedures.

Contract Termination: Farmers should be allowed to discontinue a service or halt the collection of data at any time subject to appropriate ongoing obligations. Procedures for termination of services should be clearly defined in the contract.

Unlawful or Anti-Competitive Activities: ATPs should not use the data for unlawful or anticompetitive activities, such as the use of farm data by the ATP to speculate in commodity markets.

Liability & Security Safeguards: The ATP should clearly define terms of liability. Farm data should be protected with reasonable security safeguards against risks such as loss or unauthorized access, destruction, use, modification or disclosure. Polices for notification and response in the event of a breach should be established. (US Farm Bureau 2014)

This set of principles was agreed to and signed by 34 ATPs, including some of the largest corporations, in January, 2015.

The principles are aimed at ensuring the terms and conditions which farmers sign up to are transparent, that the data is owned by farmers, and that farmers are advised in the event that their data will be sold to a third party. Farmers also retain the right to prevent the sale of the data which they own. While this is an understandable approach, in practice the nature of the notification and the response timeframe provided to farmers could undermine the intent of this principle.

The extent to which these principles will curtail the practice of burying exception clauses in detailed contract agreements is unknown. The sheer volume of terms of use agreements for computers and software users generally, and the ambiguity about what constitutes 'clear' and 'user-friendly' language versus needlessly obfuscating legalese has allowed companies to hide exclusion clauses in a manner which notionally fulfils obligations of notification and even transparency.

The principle of data portability is an important feature of these principles. It should help to ensure that farmers don't become tied to a particular service provider because of the potential loss of farm data that would occur in the event that a decision was made to change to another provider.

New Zealand Farm Data Code of Practice

The Development of the New Zealand Farm Data Code of Practice was funded by New Zealand dairy farmers through DairyNZ, and also the New Zealand Ministry for Primary Industries (MPI) and FarmIQ, a farm management software company in New Zealand. The development of the code involved 60 industry and commercial organisations operating in the agriculture sector of New Zealand, as well as individuals involved in farming and the provision of advisory services. Unlike the US code, the main focus of the New Zealand code appears to be on-farm data associated with livestock and dairy production.

The code was developed around a set of principles, which are as follows:

- Compliance with the Code of Practice will be voluntary.
- The Code of Practice will offer visible credibility for approved agencies.
- The Code of Practice will encourage open, transparent communication and management of data on behalf of primary producers and end users.
- The Code of Practice will respect intellectual property rights and encourage innovation.
- The Code of Practice will raise awareness about the availability of data.

The code incorporates some similar principles to those included in the US code. These include:

- that farmers are provided with a data access and storage agreement by service providers
- that service providers ensure that data can be accessed and disseminated at the discretion of the farmer
- that the data is securely stored and protected
- in the event that the data is sought by government, that measures are in place to render data anonymous, and that the farmer is notified of the request to access the information.

ACCREDITED • NZ FARM DATA CODE OF PRACTICE •

Farm Data Code of Practice Trademark for use by accredited organisations

Figure 17: Trademark available to be used by New Zealand companies compliant with the New Zealand Code of Practice.

Source: Dairy New Zealand (2014).

The New Zealand Farm Data Code outlines a process and an industry structure through which the code is to be reviewed and amended, and establishes a Code of Practice Authority, which has the task of regularly reviewing the code and determining whether an organisation is compliant with it. Organisations pay of cost of NZ$1400 when they initially seek accreditation under the code, and the right to display its logo in association with their products. In subsequent years, their annual accreditation renewal cost is NZ$900 (Dairy New Zealand 2014).

A related and parallel development are the New Zealand Farm Data Standards, which are a set of data standards that are being developed for recording data associated with different aspects of farm businesses. The objective is to promote data exchange and increase the opportunity for innovation in the utilisation of farm data in New

Zealand. The data standards currently under development include the following:

- Animal Data Standard
- Land Application Data Standard
- Stock Reconciliation Data Standard
- Grazing and Feed Data Standard
- Irrigation and Effluent Data Standard
- Financial Data Standard
- Chart of Accounts Data Standard.

As the development process for these standards is still underway, it is not possible to comment on the extent of industry support or likely benefits that might arise from these New Zealand initiatives.

5.3 Case studies of different data flow models

One of the challenges associated with the ever-growing flood of data being generated in associated with farm production is that not all of the data is generated by or under the control of the farmer, and there is often a need to transfer farm data to external parties which may not necessarily have any direct contact with the farmer or the farm business. To gain a perspective of the different types of data being generated by farm businesses and some of the implications of this when considering data confidentiality and privacy issues, three case-study scenarios have been developed and are detailed below.

The three data case studies have been developed based on the different flows of data ownership and access identified in recent research relevant to these issues (Janzen 2015b). The three case studies are as follows:

1. agronomic data generated on-farm about farm resources and operations
2. machine data pertaining to performance of farm machinery
3. drone and remote sensing data collected remotely (for example by satellite) by third parties.

Case study 1: Data generated on-farm about farm resources and operations

The data in question in this case study is farm productivity data generated by equipment used by the farmer as part of normal operations or through technology supplied and possibly installed by a third party with the consent of the farmer. In this case the farmer/landowner is fully aware data is being generated.

The requirement that ATPs would ensure this data remained confidential is predicated on the understanding that it is the 'farmer' who owns the data generated through farming operations, although of course a 'Conditions of Use' requirement by the ATP could be that the farmer cedes any ownership rights over the data. The position taken by both the US Farm Bureau's Privacy and Security Principles and the New Zealand Farm Data Code of Practice is that the Conditions of Use should specify that the farmer retains ownership of the data and rights to control its use, and it seems that ATPs in both jurisdictions are prepared to reflect that in their conditions of use agreements with users, irrespective of what may be the actual legal situation (Dairy New Zealand 2014; US Farm Bureau 2014).

This is perhaps a tacit recognition that irrespective of the legal position, the market appeal of the services provided by each ATP is likely to be affected by any loss of confidence amongst users about the confidentiality and security of farm data.

While this case study appears relatively straightforward, care should be taken when defining the 'farmer'. Ambiguity may arise when the farmer is not the same as the landowner. Ideally ownership of any data generated should be specified in any contract between the landowner and a sharefarmer or contractor, although it is probably reasonable to presume that this is rarely the case at present in Australia.

There is some uncertainty about the default position that would apply in this situation. Australian trade secret legislation is thought likely to be interpreted to mean that whoever farms the paddock owns the data, as they ultimately execute the processes and usually own the machinery that generates the data. Alternatively, it could be claimed that farming processes are executed on behalf of a landowner and as such data are owned or at least jointly owned by the landowner, particularly where a contract harvester is employed (Janzen 2015c).

As a default arrangement, the landowner should have the ultimate ownership control over the data including the right to share the data at his or her discretion. However, a form of agreement would be required with, for example a sowing contractor, agronomist or sharefarmer to grant limited access to the data while under contract and for that person to be able to choose to grant access to third-party agronomists or other service providers (for example to generate a variable rate zone map) on the condition that they themselves do not share data with individual property identifiers without the consent of the landowner.

At the conclusion of the contract, the contractor's access should be revoked and the landowner free to employ a different contractor under similar arrangements and with access to historical data from prior contractors.

Ultimately the philosophy should be to allow unrestricted access to data for those involved in production while preserving privacy and ownership for the landowner to the greatest degree possible.

Once the 'farmer' or owner is established, conditions of use can be written into contracts. Two major avenues of privacy protection are available to the farmer. Laws of confidentiality should be incorporated into contracts which prohibit information including data being shared unnecessarily by the contractor. Confidentiality agreements are expected to form the parameters of data exchange between owner, contractor and service providers. Use preferences or use agreements directly negotiated in the contract are expected to govern use of data as it bounces from owner (farmer), service provides, input suppliers and contractors.

Contracts also need to make clear how the farmer can access and change their data and the provisions in place for opting-out of the agreement (Office of the Australian Information Commisioner 2015).

In the event of a legal case, it is understood that any data collected on-farm (either digital or manual) is susceptible to a request for information provided it is relevant to a specific case based on criminal law. While a person may attempt to claim a public interest immunity in such situations (on the basis that the release of the information would be against the public or national interest) it is difficult to conceive of a case where public interest immunity would apply. Farmers should be made aware in any 'Contract of Use' provided by an ATP that a subpoena on the farm data could be enforced (New South Wales Young Lawyers Civil Litigation Committee 2010).

Freedom of Information (FOI) requests may apply where farm data is collected by a government agency. This could mean, for example, that an ATP which agrees to make farm data that it holds available to a government agency for research purposes may, unwittingly, create a situation where that data could be made public as a consequence of an FOI request to the relevant government agency. An exception to this situation would be in the case where the data was made available to a government statistical agency, which usually has immunity from FOI requirements. In the event the data was made available to a government agency other than a statistics agency, it may be possible that the farm data would be judged to contain commercially sensitive information and could be considered exempt from FOI requests.

Freedom of Information (FOI) request exemption based on personal information disclosure may apply in cases where the farm is both business and home. In the US, which has similar FOI laws, the US Farm Bureau is appealing against the Environmental Protection Agency's public release to environmental groups of personal details about the home locations and contact information of tens of thousands of farm and ranch families (Rodgers & Thornton 2015).

Section 5.4 of the New Zealand Farm Data Code of Practice provides general guidelines for ATPs (see below) when faced with disclosure requests. Broadly speaking, data collectors should endeavour to keep data private unless there is a compelling legal obligation, in which case the primary producer is to be notified.

> This section recognises that all organisations have forms of legal compliance, but that some organisations have additional regulatory responsibilities. Where information is required by law or regulation to be provided to other parties (for instance, an Official Information Act request), an organisation that complies with this Code of Practice shall:
>
> - avoid disclosing information that identifies an individual primary producer; or
> - notify the primary producer if individually identifying information must be disclosed.
>
> (Dairy New Zealand 2014)

Unless the information is required by law, third parties are expected to adhere to obligations of confidence whether written into contracts or arising through implication (equitable duty of confidence). Third parties must notify primary producers about any mandatory information disclosure.

On-selling data to farm commodity traders

It is not clear whether on-selling farm data (either in its entirety or in an aggregated and anonymised form) to farm commodity traders would be legal, irrespective of contract notification or farmer approval. An example may be an ATP which has available a large volume of yield data arising from harvesters on many farms as the annual harvest progresses. This information could be of strategic commercial value to farm commodity traders, enabling them to take market positions before the rest of the market was aware of that information. This might be judged to give farm commodity traders an unlawful or anticompetitive advantage, particularly in markets with a large agricultural futures exchange or markets where over the counter (OTC) swaps predominate such as Australia.

One solution is to prohibit ATPs from using the farm data to speculate on commodity markets, or from making market-sensitive farm data available to commodity speculators. The US Farm Bureau's Privacy and Security Principles for Farm Data has an 'Unlawful or Anti-competitive Activities' section as follows, 'ATPs should not use the data for unlawful or anticompetitive activities, such as the use of farm data by the ATP to speculate in commodity markets' (US Farm Bureau 2014).

John Deere's farm data policy includes a clause that holds a similar sentiment.

> John Deere will NOT use internally or share anonymized data to external parties who John Deere believes intend to use it to influence markets, provide an advantage to commodity traders or support supply hedging by food companies.
>
> (Deere & Company 2015)

It remains to be seen whether this policy will be effectively enforced. Alternatively there could be a mandated requirement that any release of such data could only occur in the form of a controlled release of anonymised farm data to the entire market, a requirement that is similar to that which applies to market sensitive releases from listed organisations.

Liability arising from poor data quality control

The liability of ATPs in the case where incorrect or faulty data has been generated is not clear. It seems likely that there are two potential causes of this type of problem, one being an equipment fault, and the other being an operator error.

In the first case, embedded equipment software may be corrupted and downstream analyses and services derived from the data may result in losses for the farmer. It would be anticipated that in such a situation the manufacturer or software supplier would be at fault, and liable to make good any damage. A challenge for farmers in this situation would be to prove that the error was the fault of the manufacturer or supplier.

In the second case – where an operator error has resulted in incorrect data (for example through incorrect calibration) the cost of any loss would naturally reside with the machine operator or software user, although in the case of a contractor (such as a contract harvester) it is possible that the liability for resulting losses could reside with that contractor.

Calibration errors have the potential to be significant, especially in the case where data derived from several different machines are being combined together. Discussions with industry personnel in the US revealed that yield sensor calibration errors of ±10% have been identified in harvesters caused by, amongst other things, incorrect settings, dirty sensors or GPS errors. One ATP has developed a quality assurance system to standardise harvester calibration, and adjusts data post-harvest by cross-referencing harvester data with storage delivery data.

Legal recourse against losses caused by downstream analytics service providers remains unclear. With the prevalence of cloud storage and open application programming interfaces (APIs) or even standardisation of data, the market will be open to third-party service providers (Open Agriculture Data Alliance 2014). It would be expected that indemnity claims would mirror those that have been made against traditional agronomy service providers. However, to date it appears that no claims have been made against third-party agronomy software providers.

Farmers would be expected to accept fault for inaccurate data if ATP proprietary software has been modified. In any case, modifying licensed on-board software would generally be prohibited by copyright law (Janzen 2015d).

Fraud prevention

The role of ATPs in preventing fraud and supplying farm data to fraud investigations will need to be defined. While ATPs would generally be expected to uphold privacy, they would be obligated to provide information where crop insurance fraud and other illicit activities are suspected.

Even if a farmer who is suspected of criminal activity asserted that their data was personal information, the ATP would still be obliged to disclose data in accordance with Chapter 6 of the Australian Privacy Principles which dictate the use and disclosure of personal information (Office of the Australian Information Commisioner 2015):

> **6.2** An (entity subject to Australian Privacy Principles legislation) that holds personal information about an individual can only use or disclose the information for a particular purpose for which it was collected (known as the 'primary purpose' of collection), unless an exception applies. Where an exception applies the entity may use or disclose personal information for another purpose (known as the 'secondary purpose'). Exceptions include:
>
> - The secondary use or disclosure of the personal information is required or authorised by or under an Australian law or a court/tribunal order.
> - The APP entity reasonably believes that the secondary use or disclosure is reasonably necessary for one or more enforcement related activities conducted by, or on behalf of, an enforcement body (APP 6.2(e)).
>
> (Office of the Australian Information Commisioner 2015)

Regardless, it may be in the wider interest to include a clause in crop insurance contracts which permits sharing of data between farmers and insurers. It is likely that the market will demand open access to investigators if crop insurance premiums are set with a reduced risk of fraudulent payouts.

Case study 2: Data relating to the performance of farm machinery

This case study refers to data automatically recorded about the performance and use of machinery on a farm. This data may include the engine running time, engine speed and temperature, GPS location, and data detailing the performance of the engine plus related systems such as the steering, hydraulics, gearbox and electrical systems. Recent model farm machinery often has in-built capability to transmit this data automatically to a cloud storage facility or to a computer system owned by the manufacturer.

Data of this kind may be used by the machinery manufacturer for further product development and telematics services – for example to alert the owner when a service is due or a fault is detected. The question of ownership is less obvious in the case of telemetric data. Manufacturers may lay claim to machine data as a proprietary trade secret (Janzen 2015b).

Irrespective of software agreements, it appears reasonable that farmers should retain the right to opt out of sharing machine data, as is currently the case with John Deere machinery. Practical implementation of such arrangements, however, is not always feasible. Equipment manufactures can embed licensed on-board software that requires upgrades and exclusive servicing by the manufacturer and affiliates. Machinery owners can be discouraged from opting out of data sharing, as this may mean that software updates and upgrades are not received. Some reduced functionality may be an unavoidable by-product of a desire to maintain greater privacy, but some may also be artificially imposed by the manufacturer or dealer to reduce of minimise support costs, or to maximise the volume of machine data available. Picking apart which is which may not always be possible.

Uncertainty around machine data ownership is not unique to agriculture (Pinsent Masons 2014). Tesla Motors' Customer Privacy Policy adheres to the basic tenet that the vehicle owner owns and has control over the dissemination and use of engine data. At the same time, Tesla advises owners that they will experience reduced functionality should they opt out of sharing telemetric data with the company:

> Please note that, if you opt out from the collection of Telematics Log Data or any other data from your Tesla vehicle, we will not be able to notify you of issues applicable to your vehicle in real time, and this may result in your vehicle suffering from reduced functionality, serious damage, or interoperability, and it may also disable many features of your vehicle including periodic software and firmware updates, remote services, and interactivity with mobile applications and in-car features such as location search, internet radio, voice commands, and web browser functionality. (Tesla Motors 2015)

Court ordered disclosure

As with data collected on-farm, machinery data is eligible to be subpoenaed provided it is relevant to a specific case (New South Wales Young Lawyers Civil Litigation Committee 2010).

Legally obligated disclosure

Confidentiality laws and legal obligations applicable to production data (discussed earlier) would also be expected to apply to machine data. If the machine data did not carry personal identifiers it would very likely be susceptible to FOI requests if the data were held by a government body (Australian Government Solicitor 2009).

Fraud prevention

Machine data may be treated in a similar way to production data in its use for fraud prevention provided it assisted detection. Manufacturers with access to machine data either through ownership rights or purchaser permission may be obligated to hand over data to enforcement authorities. As in the case of production data, sharing of machinery data between farmers and insurers could be included within crop insurance contracts (Office of the Australian Information Commisioner 2015).

Case study 3: Drone and remote sensing data collected by third parties

There are two possible scenarios relating to remote surveillance data captured for a specific farm. Such data may be obtained from satellite imagery and data retailers, or generated via the use of an UAV or drone.

In the case of satellite imagery or data, there are currently a number of different service providers, and imagery is available on virtually a weekly basis from some of these. There are no restrictions preventing any person from purchasing this data (with some minor exceptions for military installations). Anyone who is prepared to pay for the cost of the service can purchase high resolution imagery (at sub-metre precision) and data relevant to a particular farm or specific area of land. Generally, providers of these services also have available a library of images through time, enabling changes in land use to be tracked over time. While a farmer holding such imagery or data may resist making their own specific copy of it available to third parties, there is nothing to prevent those third parties, including governments, simply purchasing their own copy of the same imagery or data.

In the case of farm data or surveillance imagery captured using a drone, if the farmer has commissioned the surveillance, then the resulting imagery or data would be considered to be owned by the farmer, and confidentiality and privacy laws would apply. One area of uncertainty may be a case where the data is obtained by a contractor providing a service. In this instance, a question may arise about whether the contractor has any ownership rights over the data and imagery collected, and whether the contractor could subsequently use that imagery or data for another purpose, or sell it to a third party. It would be anticipated that this question would be dealt with in the wording of any contract between the service provider and the farmer, and in that respect the situation is no different to that involving a contract harvester whose machinery has the capacity to create yield maps. In both instances, it will be important for farmers to clarify not just the ownership of the data they are provided with, but also the limitations that may apply to any subsequent use of that data by the contractor.

In a situation where drone surveillance has been carried out which the farmer has not commissioned or authorised, the ownership and privacy issues are much less clear.

Farm data and remote imaging captured by drones might be considered personal information. That could be the case in the event that data collected was considered to be attached to private property and related income generation and farming practices. In that situation, the provisions of Australian privacy legislation would be considered to apply, but only to governments and those organisations to which the Privacy Act applies (Commonwealth of Australia 2015a).

Under this legislation, 'notification of the collection of personal information' requirements would determine much of the process by which third-party drone operators could collect farm data. Specifically, consent would be required from the farmer before farm data could be obtained. It is likely that emerging drone technology will provide more accurate data, however such improvements would not lie outside the scope of current privacy principles relating to data collection (Office of the Australian Information Commisioner 2015).

In the case of an individual operating the drone in their private capacity, it seems that the provisions of the Privacy Act do not apply.

This is by no means certain, as it is an area of law that is yet to be tested. It has also been emphasised that the difference, and therefore the legal distinction between imagery from a satellite and imagery from a drone is not obvious. As a result, differentiating between drone surveillance and remote satellite surveillance appears to be quite difficult from a policy perspective.

The Australian Government's Attorney General's Department informed a House of Representatives Committee that remotely piloted aircraft fall within the definition of an optical surveillance device of the *Commonwealth Surveillance Devices Act 2004* (House of Representatives Standing Committee on Social Policy and Legal Affairs 2014). As such, existing Australian surveillance laws could apply. However, the Committee's report also acknowledged that the surveillance laws were designed for devices physically attached to a property, and therefore their application to drones required review.

Should Australian surveillance laws be extended to drones, it is difficult to identify a reason why satellite imaging would not also be treated similarly. However, the collection and sale of satellite imagery is already commercialised, and condoned by Governments which are regular users of such services. Even in the event that Australian law restricted the availability of satellite imagery for Australian users, the same imagery can readily be obtained from international vendors via the internet, which means any restriction on the availability of satellite imagery within Australia would be largely ineffective.

The Australian Law Reform Commission has put forward the following Uniform Surveillance Law proposals.

> **Proposal 13–3** Offences in surveillance device laws should include an offence proscribing the surveillance or recording of private conversations or activities without the consent of the participants. This offence should apply regardless of whether the person carrying out

> the surveillance is a participant to the conversation or activity, and regardless of whether the monitoring or recording takes place on private property.
>
> (Australian Law Reform Commission 2014)

The complexity and uncertainty associated with these issues is highlighted by the use of drones by animal rights activists to covertly film alleged mistreatment of animals on farms. Prosecution of these groups has proven to be difficult. Animal rights groups have exploited the band of airspace above the limits of private property (30 metres) and below commercial airspace (122 metres) in order to avoid trespassing laws (Murphy 2013; House of Representatives Standing Committee on Social Policy and Legal Affairs 2014).

In the event that remote surveillance was determined to be illegal regardless of whether physical trespassing laws have been breached, activists may still find legal recourse to pursue drone surveillance as a consequence of potential exceptions to proposed laws. For example, proposal 13–4 in the Serious Invasions of Privacy in the Digital Era discussion paper by the Australian Law Reform Commission proposes the following as a valid defence in response to prosecution under surveillance laws:

> **Proposal 13–4** Defences in surveillance device laws should include a defence of responsible journalism, for surveillance in some limited circumstances by journalists investigating matters of public concern and importance, such as corruption.
>
> (Australian Law Reform Commission 2014)

This may provide an avenue for animal rights activists to sustain a defence in a case involving prosecution for undertaking covert surveillance of a farm.

5.4 The privacy of farm data

The preceding case studies highlight the complexities of the privacy issues associated with the generation and collection of digital farm information, and the legal uncertainty associated with these issues.

Generally speaking, ownership rights and subsequent use of data generated using ground-based equipment owned by a farmer will be controlled by the farmer, except in the case of machinery operating data, which the equipment manufacturers may reserve ownership rights over.

In the event that this information is transmitted to a cloud storage facility or farm software platform, the subsequent ownership rights will be determined by the ‘Conditions of Use’ provisions of that facility or software platform, a number of which now have arrangements which enable farmers to control the use of their information, and who has access to it.

Data ownership and use rights become more opaque in the event that the cloud storage or farm software facility transfers the data to a third party – even in the event that such a transfer is permitted by the farmer on whose land the data was originally generated. Ideally, data use and access permissions should ‘travel’ with the data, although whether this is legally enforceable by the original data owner is unclear, and the extent to which this applies to anonymised data is also unclear.

Ownership rights over farm data generated by a contractor (such as a contract harvester) remain unclear, unless the conditions of the contracting agreement between the farmer and the contractor specify both the ownership rights over any data generated, and the permitted uses of that data by the contractor.

There are only quite limited ownership rights available over remote surveillance data or imagery (either satellite or drone) associated with a particular farm or area of land. High resolution satellite imagery can be and is purchased routinely by corporations, individuals and government agencies, and the owner of the land from which the imagery or data was generated has no say in who could or should have access to that data.

Ownership of data generated via drone surveillance commissioned by the farmer resides with the farmer. It is not legally possible at present to prevent other individuals from using a drone to obtain surveillance data from a privately-owned area of land or a farm.

As a general rule, all farm data is susceptible to a subpoena issued by a court of law, assuming that the data is relevant to a specific legal action. This applies irrespective of whether the data is in digital or written form, and irrespective of whether it is stored on the farm or by a service provider (New South Wales Young Lawyers Civil Litigation Committee 2010).

Farm data provided to a government agency is likely to be susceptible to an FOI request lodged on that agency, except in the case of a statistical agency covered by relevant legislation that aims to ensure information contributed by individuals or businesses for statistical purposes remains confidential.

A later section of this report provides further discussion of these issues, including proposed policy responses to a number of these where it is judged they may be an impediment to the full realisation of the benefits available to the farm sector arising from digital agriculture.

6. Technological limitations of digital agriculture

New technologies invariably come with limitations or teething problems. This section explores some specific issues which are ubiquitous across digital agriculture in Australia. The first is the quality of data. The maxim ‘garbage-in equals garbage-out’ applies just as much to digital agriculture as it does more universally to any area of scientific investigation or use of data for production decisions. Data quality is essential to generating value and technological acceptance.

The second limitation in Australia is regional telecommunications’ connectedness. Most digital agriculture applications are only fully functional in situations where wireless or mobile internet access is available, and unfortunately this is not the case for many regions of Australia where digital agriculture applications might conceivably be deployed. The extent to which ATPs can adapt products to data restrictive environments will be critical to the future development of digital agriculture in Australia.

6.1 Data errors

While one of the strengths of true big data applications is that the sheer volume of information means that the impact of low-frequency data errors can be minimised, many digital agriculture applications at an individual farm level are not true big data applications in reality, and data errors can be an important limitation to the utility of any system.

Data errors can arise from a number of different sources. These include:

1. poor data quality
2. errors associated with the inappropriate use of data and analytics
3. errors that are caused by unexpected or unmeasured changes in the data environment (Reimsbach-Kounatze 2015).

These categories provided a useful framework in which to identify vulnerabilities in agricultural data.

Poor data quality

The Quality Framework and Guidelines for OECD Statistical Activities define seven dimensions of data quality; relevance, accuracy, credibility, timeliness, accessibility, interpretability and coherence (OECD 2011). The ABS Data Quality Framework also has a similar set of seven dimensions. In the case of the ABS, ‘institutional environment’ is included in place of ‘credibility’ with the other six dimensions listed being identical. The ABS notes that their framework is based on the framework adopted by Statistics Canada and the European Statistics Code of Practice.

Of these, accuracy and coherence are probably the greatest limitations to data quality relevant to digital agriculture.

Accuracy is defined by the OECD as:

> [T]he degree to which the data correctly estimate or describe the quantities or characteristics they are designed to measure. Accuracy refers to the closeness between the values provided and the (unknown) true values.
>
> (OECD 2011)

Accuracy is determined by the functionality of the technology generating the data, including the calibration processes and collecting techniques. Some sense of the challenges associated with data accuracy can be gained from a consideration of the operation of yield monitors in grain harvesters.

Generally, harvester yield monitors rely on some form of flow meter installed in the grain elevator which transfers the grain to the storage bin on the harvester. The flow meter is normally an electronic load cell, and may be subject to errors depending on how well the machinery has been maintained and the sensor cleaned. Data accuracy can also be affected by the moisture content of the grain being harvested, which is also monitored by sensors in the grain harvester. The flow meter is normally calibrated by harvesting an initial volume of grain, which is then accurately weighed and used to adjust the flow meter to correctly estimate the weight of grain being harvested.

An additional source of data error can arise from the way the yield data is collected, because the harvester is travelling across a paddock and there is a delay between the standing crop being cut by the front of the harvester, and the threshed grain subsequently flowing into the storage bin. An adjustment or delay factor is required in order to accurately associate the flow of grain into the bin with the particular part of the paddock from which that grain was harvested.

Discussions with industry personnel in the US revealed that yield monitor errors of up to 10% have been reported, arising from a combination of factors including faulty flow meters, calibration errors, and errors in GPS systems which mean that the harvester does not accurately sense when driver error has resulted in the header front overlapping a previous run.

Coherence refers to the compatibility of data obtained from different sources. In terms of data quality, a higher level of coherence allows data to be compared, aggregated and analysed with greater confidence The ability to merge and transfer datasets is pivotal to facilitating a competitive market for data analysis and avoiding separate data silos that have diminished utility.

During its initial stages, coherence was a major challenge for farmers adopting digital agriculture. Data from different machinery manufacturers were incompatible, and farmers faced the prospect of having to rely on a single machinery brand for all their farm equipment needs and also require the same of any contractors in order to fully adopt digital agriculture. This has now changed with the development of more sophisticated farm software platforms and the adoption of open access data protocols.

The open data concept is based on the preference that the data produced by each different machine/ technology is able to be accessed by software tools and converted from one form to another – not necessarily that all data are in a standard format. Unfortunately, at the present time data conversions are not always 'loss-less' and can result in information being lost in the translation, although this is steadily improving.

The remaining five data quality dimensions are of less immediate concern.

Relevance:

> The relevance of data is an assessment of the value contributed by these data. Value is characterised by the degree to which the data serves to address the purposes for which they are sought by users. (OECD 2011)

Somewhat inevitably, the ability to utilise and derive value from the data has not kept up with the volume of data being generated. Large stores of farm data in the form of yield maps are currently cluttering up the hard drives of numerous farm computers, but are not being used and are essentially valueless. This is not a significant problem as the cost of data collection and storage is relatively cheap, although it may foster an attitude amongst farmers that digital farm data is of little relevance to their business.

Credibility: Credibility as defined by the OECD (2011) refers to, 'the confidence that users place in those products based simply on their image of the data producer, ie the brand image. Confidence by users is built over time.'

The infancy of many digital agricultural applications make credibility difficult to assess. Credibility is largely governed by the reputation of the institutions collecting the data. In the case of digital agriculture many of the private data collectors and digital agriculture service providers already have longstanding relationships with customers through other non-data driven products. Much of the initial credibility of digital agricultural services will be influenced by company reputation in regard to on-farm services. Over the medium to long term credibility in the eyes of the customer base will be determined by whether farmers believe that digital information is generating returns for farmers, rather than just scientific publications.

Timeliness essentially refers to the availability of data in an appropriate form at the time it is needed in order to aid decision-making. This is generally not an issue in relation to digital agricultural applications, as most generate data instantaneously. Perhaps the only timeliness issues that arise are in relation to the availability of soil test data, which require the services of an external laboratory. Generally speaking, however, the timeliness of agricultural data is not a major limitation.

Accessibility: The ABS evaluates data accessibility under two key aspects.

- Accessibility to the public: the extent to which the data are publicly available, or the level of access restrictions. Additionally, special data services may include the availability of special or non-standard groupings of data items or outputs, if required.
- Data products available: this refers to the specific products available (eg publications, spreadsheets), the formats of these products, their cost, and the available data items which they contain.

These aspects are tailored to the role of the ABS as a national statistical organisation, however the underlying concepts remain important to agricultural data accessibility. In the case of farm data, accessibility for the public is not as important as accessibility to research organisations and service providers.

The second aspect of accessibility as defined by the ABS is concerned with 'the data products available.' In a sense this is less of a problem with agricultural data. The end products available to the public are anticipated to be data-driven applications and software rather than publications. The data products (publications) considered as part of data quality are destined for specialised service providers who then face challenges associated with user interfaces and automated systems compliance.

Interpretability: The interpretability of data products reflects the ease with which the user can understand and properly use and analyse the data.

The magnitude of interpretability issues depends on the targeted user. Digital agricultural companies are becoming increasingly sophisticated, and what is and isn't interpretable varies significantly between different organisations. Relative inaccessibility and complexity at the data collection stage may not be a limitation provided it can massaged by software systems into user-friendly products (Australian Bureau of Statistics 2010).

Errors associated with inappropriate data use

Having access to good data and analytic tools is no guarantee that sensible insights will be obtained. The sheer volume of data now able to be generated in many industries has tempted many to forgo scientific method in favour of population analytics. Using analytics, the reason for a relationship between two variables does not matter in so far as it holds true – if analytics can show that an increase of A causes an increase in B, then a user of the information need not understand the reason for this.

The first problem is that modelling interactions between all relevant variables using data analytics is rarely possible. Correlations can often be 'discovered', but with no causal relationship. An increase in A may in fact be correlated with an increase in B, but not caused by it. For example, increases in both A and B may be the result of an increase in variable C or the data may simply be implying a statistical significance within random fluctuation. Relying on analytics in lieu of understanding the underlying relationship leaves decision-makers vulnerable to a change in the wider environment in which these variables are observed. If it is suddenly observed that changes in A and B are no longer correlated, it can be very difficult to understand why relying on analytics alone.

Data has been utilised to reach erroneous conclusions in a range of different industries, and sometimes for underhanded purposes. Even qualified data researchers have been guilty of cherry-picking spurious correlations for their own benefit. Spurious correlations can be discovered when large numbers of variables find their way into big datasets (Taleb 2013).

Errors that are caused by unexpected changes in the data environment

Errors occur when data becomes distorted due to unforeseen or unmeasured changes within the data environment. For example, the confluence of weather systems, pathogens and human management can make agricultural data analysis particularly susceptible to errors arising from a changing external or unmeasured environment. This can result in distorted results which are otherwise accurately modelled under normal conditions.

Compounding these problems are potential incentives for data tampering, particularly related to farm input regulation (Reimsbach-Kounatze 2015). For example, farmers may have an incentive to obfuscate data when restrictions are imposed on the use of water or nutrients. Subsequent analysis of resulting data may result in conclusions being reached about improvements in water and nutrient efficiency that are not justifiable.

6.2 Digital agriculture and internet access

Many machinery companies now offer a wide range of in-built precision agricultural technologies that involve collecting data which helps monitor the real-time performance of a machine, field or crop. However to fully utilise this type of technology, a mobile data connection is required in order to transfer information to and from the machine to a website or digital agriculture platform.

If internet speeds are too slow then most data applications are simply an expensive and limited-use option. As a general rule, internet connections with data transfer speeds of less than 1.5 megabits per second (Mbps) are not able to transmit even relatively small yield monitor data files (Griffith et al. 2013).

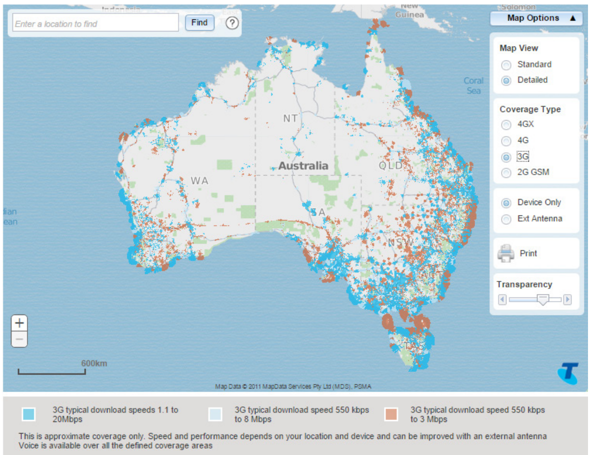

Figure 18: 3G mobile telephone coverage provided by Telstra.

Source: Telstra Corporation Limited (2015).

As the map in Figure 18 shows, there are large areas of regional Australia that do not have any mobile phone coverage, and large areas that only have very low rates of access speed.

To mitigate poor internet access speeds on farms, ATPs design applications so that a user can access all important farm information with or without a mobile telephone signal. An example is Farmobile's passive uplink connection (PUC) which can store data until an internet connection is available, and can transfer farm data from multiple different machines to a single storage site when a mobile connection is available. This permits data to be collected from machinery without major loss in functionality, albeit with slightly delayed upload to the cloud (Farmobile 2015).

For in field applications that require an internet connection – such as those which incorporate weather data – a lack of mobile access to transfer data is an issue. Applications and products are generally designed to run as close to full functionality as possible without an internet connection in order to accommodate variable data transfer speeds in rural areas. For example, variable rate planting maps are often created with the aid of online analytics, but are then exported to the on-board controllers which can execute a crop planting or fertiliser prescription without an internet connection.

Nearly all businesses in Australia access the internet using a broadband connection. However, businesses in the agriculture, forestry and fishing industry lag behind other industries when it comes to accessing broadband, building a web presence, placing orders via the internet and receiving orders via the internet. There is no doubt that the relatively low quality broadband coverage in rural and remote regions has been a major reason for the slow adoption of internet functions by these businesses.

In many cases, Australian farm businesses are operating with broadband connections that are slower, more costly and less reliable than those available in other nations that compete for similar agricultural export market opportunities, such as Denmark, the US, New Zealand and Canada. As a result, there are many Australian farmers who could remain years behind global peers in technology adoption due to inadequate internet access.

Regional Australia is scheduled to receive faster and more reliable internet from the first half of 2016 with the roll out of the NBN. The first of two satellites was launched in October 2015 as part of regional satellite broadband network designed to enable wholesale download speeds of 25 Mps. Data will be transmitted to and from fixed receivers attached to regional homes and businesses. This is expected to improve internet access for many farm businesses, however fixed receivers will not be able to transfer real-time data from operations in field (NBN Co. Limited 2015).

7. Discussion and recommendations

Digital agriculture is developing at a very rapid pace, driven by technological developments occurring external to agriculture which are leading to an inexorable reduction in the cost of computer power and digital technologies, very rapid growth in the use of smartphones and mobile computer technology, and the global growth of the internet. Some sense of the rapidity of change can be obtained from the observation that the first ‘smartphone’ was released by Apple in June 2007, and since that date there have been over 700 million iphones sold by Apple worldwide, as well as countless smartphones sold by other manufacturers. (Ingraham 2015).

The rapidity of these changes makes it difficult to project likely future digital agriculture developments with any certainty, and hence to propose industry initiatives or government policy settings that may have beneficial impacts. The pace of change makes it highly likely developments will overtake industry or government initiatives, even before they are implemented. An added complication from an Australian perspective is that sub-sectors of Australian agriculture are likely to inherit digital agricultural platforms and systems that have been developed in the US, and these will have been developed within a policy framework and science base associated with that market, meaning the opportunity to develop unique Australian versions of these systems may be limited.

These qualifications noted, it is instructive to review some of the strategic developments that have occurred in digital agriculture in the US as it has evolved. The first developments arose in response to the possibility of more precise crop management brought about by the incorporation of GPS technology into the control systems of farm machinery during the 1990s. Harvester yield maps created the opportunity to plant and manage crops at a sub-field level in response to evident variations in soil and other variables, once data had been accumulated over a number of years.

During these early stages, farm input and machinery suppliers provided digital agricultural systems as a loyalty incentive for users of their products, and many developed unique systems in order to make it difficult for farmers to swap to competing suppliers without losing their farm’s digital assets.

However, alternative software and digital platform suppliers quickly emerged and provided farmers with the ability to divert farm digital information away from proprietary platforms, and also to translate the digital information to formats that were compatible with alternative systems. At the same time, it seems that owners of the proprietary systems came to the realisation that it would be difficult to service all the software needs and desires of farmers, and that it was strategically smarter to provide platforms with open access arrangements that encouraged a competitive market to develop for specialist software applications.

Consequently, over recent years digital agriculture systems in the US have been democratised. Farmers can now choose from competing platforms and systems, and can store information arising from a range of different machinery and technology brands on a single platform. They can also choose preferred software applications to manipulate or analyse that data from a competitive software marketplace, and are largely able to switch between different platforms and systems without a significant loss of data.

Australian crop producers, in particular, have adopted elements of digital agriculture (often referred to as ‘precision agriculture’ in the cropping context) to a greater degree than their US counterparts, especially controlled-traffic farming, minimum or no tillage and GPS guidance systems, but have not adopted variable rate cropping applications to the same degree, and do not have available the software and digital platforms available in the US market. It is evident that a commercial digital agriculture software market has not emerged in Australia to the same extent as has occurred in the US.

The smaller scale and greater variety of Australian cropping industry sub-sectors is undoubtedly a factor limiting software development, as is the much lower level of private sector involvement in seed breeding in the cereals industries compared to the US corn or soybean industries. A further factor that may be inhibiting software development is the lack of detailed soil and climate data in Australia, recognising that while the US soil data may be somewhat imprecise within fields, it does at least provide a platform to build from. A further limiting factor in Australia appears to be that Australian university researchers and the CSIRO do not have good track records in engaging with industry and transferring knowledge to the private sector in order to enable it to be commercialised and developed.

One thing that is very evident from observing developments in the US is that it is the private sector which has taken the lead in developing software systems and platforms that are user-friendly and commercially appealing, not public-sector researchers. What is also very evident is that it is data analytics and software specialists that have been at the forefront of commercial digital agricultural developments in the US, not plant and animal scientists.

To facilitate faster development of commercial digital agriculture applications in Australia (encompassing livestock, cropping and horticulture sectors) there appears to be merit in creating a regular, structured forum involving agricultural scientists with appropriate technical knowledge and experience, software and information technology specialists, and farm input suppliers or service organisations with an interest in developing digital agriculture platforms or specific applications.

There are existing organisations and industry bodies already operating in this space to some degree, such as controlled traffic farming groups and precision agriculture groups. These are generally focused on the broadacre cropping sectors. Given the rapid development and likely future growth of digital agricultural applications in the livestock and horticulture sectors and the desirability of having broad, cross-agriculture engagement in these issues, it is felt that the label 'digital agriculture' is preferable to 'precision agriculture', in order to ensure there is a clear understanding that the forum encompasses the full breadth of agriculture, and not just the cropping sector. It also recognises the reality that Australian farms are more likely to be mixed enterprise farms than is the case in the US, and that there is therefore likely to be advantages in the development of systems and platforms that have the potential to accommodate multiple different farm enterprises, rather than just focus on a single enterprise.

Recommendation 1:

Australian agricultural industries, Australian agricultural research agencies and relevant IT, telecommunications and software organisations should collaborate in the establishment of the Australian Digital Agriculture Forum, with the broad objective of advancing the development and adoption of digital agricultural applications and systems in Australia.

Convening such a forum on a regular basis has the potential to assist in the development of networks between the various disparate groups that might have an interest in advancing these developments, and in particular creating avenues to commercialise the delivery of digital agricultural applications in Australia.

The establishment of a forum involving all relevant interests across the entire agriculture sector creates the potential to develop, where necessary, industry-wide standards. This will assist in ensuring that a competitive digital agriculture service market develops, that there is industry-wide agreement on issues such as interoperability, transferability, data ownership and privacy. It will ensure that the potential exists for concerted industry action on issues such as telecommunications network infrastructure, and policy issues that may impact on the development of digital agriculture in Australia.

While developments in digital agriculture in Australia – or certainly in the development of integrated software platforms and systems – lag those in the corn industry in the US, this provides an opportunity to learn some lessons from the developments that have occurred, and the subsequent evolution that has occurred in the digital agriculture system of the US.

Data ownership and access

Perhaps the first lesson to emerge has been that attempts to develop digital agriculture systems as proprietary systems limited to one particular machinery manufacturer or seed company have not been successful, and both technological developments and the desire of farmer clients to have access to interoperable systems has meant that open access data arrangements quickly evolved. This means that farmers using a number of different machinery brands on their farm can still have all their farm data located on a single storage platform, and that the same information can be utilised by a number of different applications. It also means that farmers are not 'tied' to a particular machinery brand or software system and can choose to move to an alternative system without a subsequent loss of accumulated farm data.

Open access data arrangements are based on the intrinsic understanding that farmers who generate digital farm production data retain ownership of that data, and have a right to dictate the purposes for which that data can be utilised. These two principles – farm data ownership and the requirement that data should be able to be seamlessly transferred between different systems and providers – have been fundamental to the development of digital agricultural systems in the US, and there seems very strong logic that similar principles should be adopted in Australia. These principles are potentially the subject of discussion and ideally agreement by members of the proposed Australian Digital Agriculture Forum, although the research conducted as part of the project reported here has led to a very strong recommendation that both these principles should be adopted, and are necessary in order to provide a solid foundation for the development of digital agricultural systems in both the cropping and livestock industries in Australia.

Recommendation 2:

It is recommended that Australian agricultural industries, agricultural technology providers and digital agriculture platforms and software system providers should adopt as a key principle that the farmers who own the land or livestock from which digital agricultural production information is obtained retain ownership rights over that data. This includes the ability to determine the uses to which that information can be put, and the persons or organisations which can obtain access to that data. Where contractors and sharefarmers are employed, it is recommended that a standard contract be developed that defines data access protocols for each party.

Recommendation 3:

It is recommended that Australian agricultural industries, agricultural technology providers and digital agriculture platforms and software system providers should commit to open access data protocols, modelled on the standards adopted by the Open Agriculture Data Alliance established in the US.

Data privacy

One of the key issues that has the potential to limit the development of digital agriculture in Australia is concern about the privacy of farm data. The concept of privacy in the digital era requires a re-evaluation of existing concepts and arrangements. As earlier discussion has highlighted, control over farm data collection and information dissemination has been highly diminished by technological developments. It is now entirely feasible for satellite imagery or machine telemetry data to be utilised to obtain detailed information about farm operations without a farmer having any awareness this information has been collected. This data can be combined and fed into increasingly sophisticated algorithms which allow for private information to be inferred well beyond the scope of original datasets.

Attempting to apply privacy controls over the collection of data is increasingly untenable. For example, the information contained within telematics data captured by farm machinery may be collected for the purpose of monitoring machinery performance and diagnostics. This data combined with other public and private data (for example from soil testing laboratories) has the potential to reveal information including soil type, operator competence, operational processes and crop yield. Similar issues arise for data derived from livestock industries. National Livestock Identification Scheme (NLIS) information combined with post-slaughter abattoir data can provide very detailed information about a livestock business. Similarly, the data collected and held by dairy processors provides a very detailed picture of the operations of the businesses of their farmer suppliers.

Put simply, the volume of data and the analytics at the disposal of third parties makes quarantining farm digital information increasingly problematic.

It should also be recognised that imposing onerous restrictions on the collection and use of farm data runs the risk that such measures will seriously curtail the necessary research and development that has the potential to provide insights that have the very real potential of delivering much-needed productivity gains for Australian farmers.

This issue was addressed in a general sense in a recent report prepared for the US Government entitled, *Big data and privacy: a technological perspective* (President's Council of Advisors on Science and Technology 2014). In seeking to address concerns about data privacy, the report questions the legislative wisdom of focusing on data collection and algorithms in isolation. Neither data, nor the accompanying algorithms can be considered harmful to society. Information derived from combining the two can, however, be *used* to infringe upon individual's rights to privacy. A key recommendation from the report was that, 'Policy attention should focus more on the actual uses of big data and less on its collection and analysis.'

Focusing on the use of data rather than collection and analysis has the added benefit of allowing legislation, regulations or guidelines to be developed without referencing technology. As a general principle, policy measures should be technologically neutral wherever possible so as to preserve relevance as the technology evolves.

Privacy rights are most commonly determined through a use agreement which consumers would recognise as a software licensing agreement that is 'ticked and flicked' when accessing new computer software or other applications.

In theory, this approach makes sense. The user of the data collecting product or service agrees to what, with whom, and how their personal data will be used. In practice however, these agreements are frequently written in a way that obfuscates key exception clauses which the user must accept as a condition of use.

The privacy exceptions hidden within the legalese of user agreements for agricultural machinery may not be as complex as some others, but they are still likely to be significant. It has been recognised internationally that even these are impractical for farmers to read, comprehend and potentially negotiate with manufactures and suppliers handling their data.

The US Farm Bureau, in conjunction with major industry service providers, developed a set of Privacy and Security Principles for Farm Data to which the signatories agreed to be bound. Similarly, The New Zealand Farm Data Code of Practice establishes industry practices for compliant organisations, and provides accreditation for compliant services or products (Dairy New Zealand 2014).

This requirement to satisfy a code of practice places a degree of faith in participating organisations to adhere to the agreed standards, but also leaves open the potential for differing interpretations of that code.

For example, does a requirement not to disclose information to third parties for commercial benefit apply to all data, anonymised data or aggregated data? It would not be surprising if there were different answers to this question, depending on the person asked. The report by the President's Council on Advisors on Science and Technology referenced earlier recognised this issue, and proposed the appointment of an intermediary (a data ombudsman) to digest the terms of use associated with software and provide an assessment to the marketplace (for example via accreditation) of whether the product or service adheres to a set of overarching agreed principles similar to the US Farm Bureau's Privacy and Security Principles for Farm Data or the New Zealand Farm Data Code of Practice.

The belief underlying this proposal is that as the market starts thinking about approval from the intermediary (the data ombudsman) as part of a purchase decision, software and service providers will recognise the commercial imperative and comply with these standards, otherwise potential purchasers will seek out other suppliers.

The role of an ombudsman could be extended to afford farmers greater control over the use of data by technology suppliers and third parties, recognising that not all farmers will make the same privacy demands of their software providers. An ombudsman might not only accredit different software products against an industry standard, but may also facilitate the ability of farmers to personalise the uses and access arrangements for their data. This could be a way of avoiding a situation where farmers are faced with a binary (yes/no) decision about the use of their data by third parties, and automatically opt to prevent access by third parties, irrespective of how benevolent or useful that third-party access may be.

For example, an intermediary accreditation body could define different use categories for farm data, such as direct marketing by third parties, private research, public and higher education research, farm financial analysis, and property valuations etc, which the farmer could select at their discretion. On the purchase of software or the establishment of a user account, a farmer may be presented with a data use option table with standardised use options similar to those in Table 3.

Table 3: Example of standard use options that may be made available for farmers.

ATP data use options	User preference
Telematics machine monitoring services	Yes only
Private product development	Y/N
Private customer research	Y/N
Public and higher education research	Y/N
Direct marketing (software provider only)	Y/N
Direct marketing (external company)	Y/N
Real estate property valuation	Y/N
Commodity trading	No only

The ombudsman would be expected to have the capability to monitor data usage, ensuring that it was within the bounds of the pre-selected user preferences.

Tracking use preferences post- as well as pre- analysis represents a formidable challenge. Algorithms operating on data will need to be vetted according to output properties. The President's Council of Advisors on Science and Technology report highlights the use of data tags and attributes to ensure fidelity to the original purpose as data output proliferates through analysis.

> The privacy policies of the output data must be computed from the policies associated with the inputs, the policies associated with the code, and the intended use of the outputs (ie the context).These privacy properties are a kind of metadata. To achieve a reasonable level of reliability, their implementation must be tamper-proof and 'sticky' when data are copied.
>
> (President's Council of Advisors on Science and Technology 2014)

The report acknowledges that formalisation and implementation of these policies is very much a recent phenomenon and much of the target technology is still in the research phase. Nevertheless, demarcating the use of data throughout larger organisational structures has been shown to be workable.

Recommendation 4:

It is recommended that Australian agricultural industries, agricultural technology providers and digital agriculture platforms and software system providers should support the appointment of a Farm Data Ombudsman to oversee data privacy standards, to establish data use categories, and to audit compliance by providers with industry data privacy standards.

An ombudsman would function as a supplement to agreed privacy principles. Farmers should still be able to exercise the right to address and negotiate contracts directly and be encouraged to do so. It would still also be highly recommended that farmers review their contracts and are educated in their privacy rights where possible. However, it is also recognised that farmers cannot be expected to be IP lawyers, data scientists and an IT department. Serviceable default privacy settings and rights for the many who simply don't have the time or capacity to scrutinise privacy agreements are a necessity.

The office of the data ombudsman would be responsible for setting a list of prohibited and mandatory clauses which would (ideally) be developed in conjunction with major ATPs and other stakeholders. The list would require periodic review as well as mechanisms for triggering reactive assessment of clauses similar to those within the New Zealand farm data code of practice.

Signatories to the resulting data privacy standard could receive certification in much the same way as those who comply with an industry code of practice. Alternatively the ombudsman would simply maintain an updated list of compliant organisations available to the public.

The position of the data ombudsman would ideally be reviewed every five years to determine whether the position remains necessary, as it would be anticipated that user understanding of agreements should become 'normalised' over such a period.

Farmer education

Education has long been seen as a necessary measure to ensure farmers can effectively adopt new technology and more recently, arm themselves with knowledge to help protect themselves against privacy violations. The privacy rights of farmers will potentially be curtailed to some extent under contracts with digital agriculture providers, and as such, it would be desirable that education programs on data privacy be developed for farmers. The Australian Centre for Intellectual Property in Agriculture (ACIPA) is one group which provides research and extension services which educate farmers on contract law and application (Australian Centre for Intellectual Property in Agriculture 2015). This organisation and others could work with the proposed Data Ombudsman to deliver education programs to farmers.

Empowering farmers to negotiate better outcomes or at the very least encouraging them to read and comprehend privacy clauses is a laudable goal, however, this should not become the first line of defence against privacy violation for all farmers. Between the turmoil of big data development and time constraints of farmers, care should be taken to avoid overburdening farmers with legal obligations. Education should be seen as a supplement to industry privacy standards.

Data anonymisation

Data anonymisation has been useful in the past, particularly for research purposes whereby personal information is detached from the data, while sufficient classifiers remain for analysis. For example, few farmers would be concerned if data detailing attributes such as soil, weather, geographic region, or crop yield were accessed for public research purposes, if the data was anonymised and could not be attached to individuals or their property.

Anonymisation has served to allow the use of private data while removing privacy concerns. Unfortunately there is growing doubt as to whether anonymisation techniques can protect privacy as big data analytics evolve and proliferate. Reservoirs of historical data and analytics software can take new anonymised data and infer information not apparent in the dataset alone. The President's Council on Advisors on Science and Technology report concluded data anonymisation would be better suited for use as additional safeguards rather than in the policy framework.

Data analytic skills

In a recent report into big data and Australian agriculture, it was identified that a shortage of data analytics talent within the Australian agricultural sector could be a major limiting factor in the development of digital agriculture in Australia (Allen 2015). Agriculture will to have to recruit data analytics talent from a highly contested, external labour pool. Indeed, as one senior industry participant in North America pointed out, the last people that should be appointed to these roles are plant or animal scientists. They are trained to analyse very specific results arising from tightly controlled trials, usually where only one or two independent factor are subject to variation. By contrast, data analytics involves searching for trends or relationships between different factors utilising very large sets of data, in which all the variables may be uncontrolled. Plant and animal scientists, as a consequence of their training, are generally not proficient in big data analytics.

The establishment of an Australian Digital Agriculture Forum, as proposed earlier, may provide a very useful opportunity to develop programs that will assist in attracting skilled data personnel to the Australian agricultural sector.

New or modified university courses and degrees should play a role in meeting the potential demand. One avenue is the creation of an elective agricultural bridging course embedded within data science/mathematics degrees. This would equip data scientists with an understanding of potential applications within the agricultural sector, thereby reducing the training burden incurred by agribusiness in bringing data scientists across. It may also become an important tool in attracting data science talent.

From an agricultural science perspective, there may be scope for a new cross-disciplinary degree. ICT and data science courses would form a large component of the syllabus along with farming systems. Students who complete the degree would ideally possess knowledge of design and application of sensing technologies, and big data analytics in addition to specialised knowledge of farming systems. It would be expected that much of the syllabus would be aligned with Agricultural Engineering degrees already taught in Europe, and North and South America.

Role of national statistics services

The role of national statistics organisations (NSO) such as the Australian Bureau of Statistics (ABS) will need to be considered as digital agriculture proliferates.

The OECD raised the possibility that an NSO could function as a 'clearing house' whereby they would set standards for the data and guidance for its usage and associated limitations. There is a possibility that a 'clearing house' of this sort may be useful, but whether the ABS is best placed to take on this role is debateable. It would be preferable for the agriculture sector to manage and control the industry-good elements of digital agriculture (as has occurred in the US), and for the ABS to consider opportunities to take advantage of the resulting datasets, as and when it might be appropriate.

Cross-referencing data between NSOs and private datasets could have the effect of improving the quality of both if managed correctly. An example is the US company Farmlink, which has the capacity to use harvester yield data from a large number of harvesters to calibrate remote imagery and obtain quite accurate regional and nation crop production estimates (Farmlink 2015) – at obviously much reduced cost in comparison with methods of estimation that are currently used to generate official statistics. Collaboration between this organisation and the USDA could result in important accuracy and efficiency gains, which would benefit both.

Role of government, researchers and industry

The evolution of digital agriculture in the US provides some very useful insights into the respective roles that can usefully be played by different groups and organisations in facilitating the development of these technologies and systems.

The US Government or respective state governments do not appear to have a direct role in digital agriculture in the US, yet have played a very significant role in enabling these developments to occur. Private sector participants acknowledge that there are a number of different pieces of infrastructure that have been provided by governments, without which digital agriculture would not have evolved to the extent that it has. These include in particular:

- The detailed 1:25,000 soil maps and associated data that provides an important basis of many of the digital agriculture software systems used in the cropping sector of the US.
- The comprehensive climate data that is available from a network of high density weather recording stations and weather radar sites in the US.
- The comprehensive mobile telephone coverage and GPS correction networks that are available, combined with ready access to cadastral data and remote imagery.

Australian governments and research agencies have begun to augment available soil maps and to combine these with soil information obtained from recent soil carbon projects, but it is understood that the quality and completeness of Australian soil maps is greatly inferior to those available in the US. There have also been some recent initiatives aimed at improving the coverage of weather recording stations and weather radar sites, but again these are considered by most to result in climate datasets that fall well short of the comprehensiveness of datasets available in the US, and which have formed part of the essential underpinning infrastructure for digital agriculture systems.

The recent efforts by governments in Australia in relation to soil and climate data are welcomed, but will require much increased and sustained funding to bring these datasets up to a standard required for digital agriculture applications. Whether this is feasible in Australia, given other government budgetary pressures, is a challenging question.

There are, however, alternative public/private models emerging that may have the result of producing the desired climate and soil resources, but at a reduced cost. In the case of soil data, there would appear to be merit in exploring the potential for the results of farmers' routine soil tests to be combined with available public data to 'fill in the gaps' in the national soil inventory. It is understood that there may be issues in relation to variations in the quality of soil testing by private laboratories, but mechanisms are available to improve the consistency of different soil testing laboratories, and this would greatly benefit government and industry.

In the case of climate data, fully automated and highly accurate weather recording stations can now be purchased by individuals for between $5000 and $15,000. These are highly accurate and can be set up to transmit data to a website which can integrate available public and private climate data at specific locations, creating a much better and more localised climate dataset. Incentivising farmers to install these could have the desired result of substantially improving the quality of Australian climate datasets at less cost than would be the case if relying solely on public funding to enhance this infrastructure.

Recommendation 5:

Australian governments should increase available funding for soil mapping and weather recording stations, and actively investigate the potential for public/private investment models and private-sector collaboration as a mean of improving the soil and climate datasets that are an essential foundation of digital agricultural systems.

A key factor in the adoption of digital agricultural systems in the US is access to mobile and data networks. Some digital agriculture systems and platforms are able to function in the absence of data coverage, but at reduced functionality and in ways that add to the complexity of operation of these systems, and hence slow adoption. Data coverage is deficient in many parts of rural and regional Australia, and this has the potential to be a key limiting factor which will delay adoption and stall potential productivity gains that might otherwise be available.

The Australian Government has acknowledged the deficiencies in mobile and data coverage in rural and regional Australia with recent announcements about added funding to augment coverage in mobile telephone blackspots, however, as the recently released *Regional Telecommunications Review* (2015) noted:

> Despite these gains, and the fact that Australians enjoy among the highest penetration of mobile broadband in the world, the low population density over the remaining geography means that new approaches are needed to assess the priorities of those in the 70 per cent of Australia's land mass that has no mobile coverage, and to improve poor coverage elsewhere.
>
> (Commonwealth of Australia 2015b)

The *Regional Telecommunications Review* considered strategies such as the utilisation of infrastructure for emergency services and mining as ways of augmenting existing mobile telephone coverage, recognising that public funding alone is not likely to result in adequate coverage.

New technologies are now emerging that make private investment in telecommunications infrastructure more feasible than was the case in the past, and create the potential for cooperative models between governments, landholders and telecommunications companies to expand the mobile broadband network in rural and regional Australia. These cooperative models need to be developed, and utilised alongside increased funding for mobile telephone coverage to remove a major impediment to the rapid adoption of digital agricultural systems in Australian agriculture.

Recommendation 6:

Lack of access to mobile and data coverage is a major impediment to the adoption of digital agricultural systems. Australian governments should increase available funding to augment access to networks in rural and regional Australia, and actively investigate the potential for public/private investment models as a means of further enhancing data coverage.

While it can sometimes be overlooked, public agricultural research agencies have played a very important facilitating role in the development of digital agriculture in the US. The research findings arising from public agricultural research provide the fundamental knowledge about plant and animal growth that ultimately underpin probabilistic decision-support tools that will be at the core of digital agricultural systems in the future. The data arising from numerous crop, pasture and livestock production trials augment that knowledge bank over time, and enable computer models to be constantly improved.

Public research agencies can facilitate the development of digital agriculture by adopting open access data protocols when publishing research findings, and by including standardised information (such as geographical location, soil type, seasonal conditions, soil test data, pasture type and availability, livestock feeding regimes etc) and appropriate metadata as part of the published datasets associated with research outcomes.

A plan to implement such a system for USDA funded agricultural research was developed in the US in 2014, and is currently in the process of being adopted. Australian governments and rural research and development corporations have the capacity to make this a formal requirement of research grants for relevant research projects they fund, and should implement a collaborative program to adopt this approach.

Recommendation 7:

Australian governments and rural research and development corporations should collaboratively develop a strategy to make the detailed data and relevant metadata associated with publicly funded research available in accordance with an open access data protocol, and work to standardise the availability of other relevant information about research trials.

In many instances, research organisations such as universities and the CSIRO have resisted providing open access to research outcomes because of a concern that this would diminish the potential to generate revenue from intellectual property rights. In reality, however, there are few agricultural research outcomes that have ever resulted in the generation of significant intellectual property rights, with the exception being specific cases (such as the development of genetically modified cotton varieties in Australia) where there was a clear intent to commercialise the outcome, and the work was carried out in collaboration with commercial partners.

In most instances, it would be preferable to make publicly funded research outcomes more freely available to industry including potential commercial developers, in the hope of speeding up any potential adoption opportunities. The 'Easy IP' model initially developed by the University of NSW (UNSW Innovations 2016) and subsequently adopted by a number of other Australian universities provides an example of this approach, making much of the intellectual property generated by university research available for free for commercial applications utilising a simple, single-page agreement.

It is also essential to recognise that public research agencies are unlikely to have the skills and commercial adoption pathways available to develop and maintain digital agriculture applications.

It is notable that, while public research findings provide the fundamental underpinnings of many of the digital agriculture systems in operation in the US, the successful applications have all been developed by the private sector, and many are utilised by farm service providers, rather than by farmers themselves. Rather than direct adoption by farmers, the adoption pathway for these systems has been via commercial service providers.

Publicly-funded agricultural research is fundamental to the future success of digital agricultural applications in the US and Australia, but publicly funded research agencies should not be involved in the development of commercial software applications or digital agriculture platforms for adoption by farm service organisations or farmers. The private sector is much better equipped to perform this role.

Recommendation 8:

Australian publicly funded agricultural research organisations have a fundamental role in the generation of knowledge to underpin digital agriculture applications, models and algorithms, but should not be involved in the development of commercial software programs or digital agriculture platforms that will be used by farm service organisations or farmers.

Digital agriculture has the potential to fundamentally change agriculture in Australia, as it is likely over time to result in completely new and novel ways for farmers to access information, to record farm performance, and to integrate objective but complex farm data in ways that support decision-making. In many respects, digital agriculture represents a new information supply chain to and from farm businesses, and its adoption will constitute a dramatic change in the processes that have been collectively referred to as agricultural extension.

The software applications and platforms that enable farmers to more easily manage functions such as soil testing, crop and animal input ordering, farm record keeping, the development and management of cropping plans and grazing rotations, and many other routine farm planning and operational functions will also have the potential to supply highly specific and targeted 'extension' information relevant to each of those functions.

A farmer (often in conjunction with a professional advisor) using a particular platform or software application for ordering cropping inputs such as fertiliser or herbicides or contemplating the purchase of livestock genetic material will have the capacity to instantly compare the performance and price of alternative products, check the likely delivery timing and price, obtain a quotation for the cost of delivery, and check the availability and price of any required contractors associated with their use. At the same time, all the relevant technical information including comparative trial results, withholding periods and export slaughter intervals will be able to be made available and accessible to the farmer at the click of an icon.

These systems will not develop instantaneously, and there will be at least a decade or more during which they will be progressively developed and adopted. This means that they will not necessarily provide a new, universal extension pathway in the near future, but will rapidly increase in importance as an extension pathway in the not too distant future.

Given that the successful digital agriculture systems and platforms will almost certainly be those developed commercially, rather than by government agencies or rural research and development corporations, there will need to be some carefully considered strategies developed by rural research and development corporations and state government agriculture agencies in order to optimise the opportunities that digital agriculture provides to become a new and extremely efficient agricultural extension system.

Recommendation 9:

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

The explosion of digital information and computer processing capacity is rapidly changing the way in which businesses in all sectors of an economy operate, and some of the best resourced businesses (major media companies, for example) have struggled to respond to the challenges arising as a consequence of digital disruption. It would be a mistake to imagine the farm sector is immune to, or isolated from, these changes.

The opportunity is available to take advantage of these changes, or to ignore them and become victims. Australian agriculture is at a critical point at present, and will require sound strategic planning and clear thinking in order to take full advantage of the changes that are rapidly unfolding.

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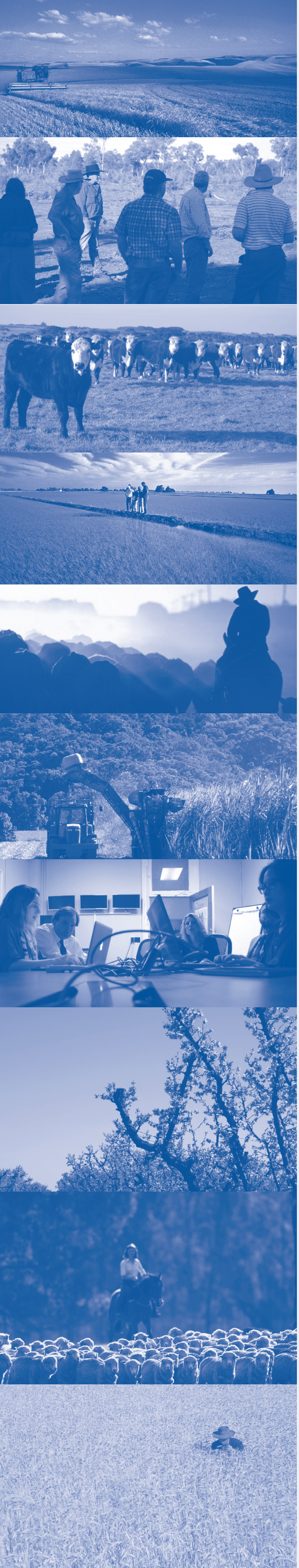

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