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Smart Farming:

leveraging the impact of broadband and the digital economy

Australian Centre for Broadband Innovation

NSW GOVERNMENT

une University of New England

The Australian Centre for Broadband Innovation
CSIRO Digital Productivity and Services Flagship
Precision Agriculture Research Group (PARG)
University of New England

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Contents

Foreword

The announcement that Armidale in the northern tablelands of NSW, would be one of the first locations on mainland Australia for the rollout of the National Broadband Network, was the catalyst for this report on smart farming. The concept of developing a Smart Farm to explore and demonstrate what new digital services could be enabled by broadband was conceived through a workshop involving staff from CSIRO and the University of New England.

It was intended that the project would provide a practical way to show the benefits of broadband to farmers and related agribusiness companies and organisations. The other goal was to make the Smart Farm accessible online to students, across Australia, to discover more about what happens on a modern farm.

The concept of Smart Farming has also been explored with a number of parallel developments involving CSIRO partnerships with the Digital Homestead and Sense-T projects. CSIRO's Sustainable Agriculture Flagship has been a leader in developing many of the concepts and tools for smart farming. The Sense-T program, have been scoped by CSIRO and its partners to explore the wider economic opportunities for using agricultural and related data from sensors networks.

This industry paper has been published by the Australian Centre for Broadband Innovation (ACBI) and the University of New England (UNE) to create greater awareness and understanding of the potential for a smart farming enabled by broadband and digital services. The report is not intended to be comprehensive in terms of the full range of smart farming initiatives across Australia, but rather illustrate the broad opportunities in a practical way for potential users.

It is also proposed that this paper will also help generate interest from relevant stakeholders in the broader agribusiness sectors to explore these opportunities through the wider trialling and adoption of new sensor and digital services.

Acknowledgements

ACBI is a collaborative research initiative led by CSIRO in partnership with NICTA, Australia's two leading Information and Communications Technology (ICT) research organisations. ACBI is part of the CSIRO Digital Productivity and Services Flagship and draws on the broad and diverse research capabilities of CSIRO and NICTA to demonstrate, develop and evaluate innovative new services and applications that are enabled by next generation broadband networks. Funding support for ACBI has been provided by the NSW and Tasmanian Governments.

The University of New England was the first Australian university established outside a capital city. UNE has a well-earned reputation as one of Australia's great teaching, training and research universities. The Precision Agriculture Research Group (PARG) is a multi-disciplinary team of academic, research and technical staff engaged in the development and application of sensors and practices in precision agriculture.

The authors would like to thank the following for their advice including: David Henry, Raj Gaire, Michael Compton, Greg Timms and Daniel Chamberlain from CSIRO; Greg Falzon from University of New England; Gordon Foyster and Chris Andrews from Taggle; Robert Crossley from Agtrix; Joe Dennis from NBN Co; and David McKeon from National Farmers Federation.

Executive summary

Australia's agricultural and upstream service and processing industries face a range of new opportunities and challenges. There is growing global demand for food and the National Food Plan has scoped the opportunity for Australia to increase the value of its agriculture and food related exports by 45% by 2025. In order to realise this opportunity, Australia needs to increase its level of innovation and improve productivity in the agribusiness sector. It must needs to do this through better use of its finite resources through the adoption of more environmentally sustainable farming practices.

This situation requires that Australia's rural sector must make a step change in its productivity. CSIRO's Sustainable Agriculture Flagship has set a national goal of increasing of increasing productivity in the sector by 50% by 2030 while reducing net carbon emissions per unit of food and fibre by at least 50 per cent between now and 2030.

The rollout of Australia's next generation broadband network and the growing impact of the digital economy through the adoption of smart digital services has the potential to help the rural sector meet its productivity and sustainability challenges.

While computing and sensor technologies have been used on Australian farms for the last two decades, adoption has been uneven and the full potential unrealised. Through the digital economy, there is a confluence of developments that will help transform the effectiveness and ability of digital services to drive innovation. These developments include:

- The National Broadband Network will create broadband hotspots on all Australian farms that can enable a broad range of digital services;
- Low cost and ubiquitous sensor technology will create "an internet of things" including collecting information on crops, livestock, water, weather, farm equipment and other things;
- The availability of spatially-enabled, mobile sensing technologies for characterising farmscapes and measuring changes in biomass;
- Local wireless systems that make it easier to connect up this "internet of things";
- Smart personal devices and apps will make accessing information on the move easier;
- Cloud computing technology that simplifies access to and sharing of information;
- The growing ability to analyse diverse information sources (referred to as "big data") using cloud computing capacity; and
- Increasing ease of use of video-conferencing systems will make it easier to bring remote veterinary and other agricultural advisory services onto the farm, many of which can be supported by in-situ sensor technology.

In order to demonstrate and evaluate the impact of these developments, CSIRO has helped establish a series of smart farming initiatives throughout Australia. The Australian Centre for Broadband Innovation (ACBI), a collaborative research run by CSIRO has worked with the University of New England (UNE) to set up the demonstration Kirby Smart Farm in Armidale in northern NSW to explore and demonstrate the impact of broadband and related digital services for Australia's rural sector.

Through this project, CSIRO and UNE have developed a flexible platform to support future smart farming applications and services. The Kirby Smart Farm has deployed a series of sensors to monitor soil moisture, temperature and livestock, which together create an information stream to support flexible decision making for pasture and livestock management. Local wireless networks allow the fixed and mobile sensors to send a continuous stream of data to a remote cloud based computing and analytic service. The information platform is supported by a baseline farm database comprising of numerous spatially-enabled 'information 'layers' (eg fencelines, topography, soil characteristics) using commercially-available technology.

CSIRO is also leading and collaborating with a number of other smart farming related projects. These include:

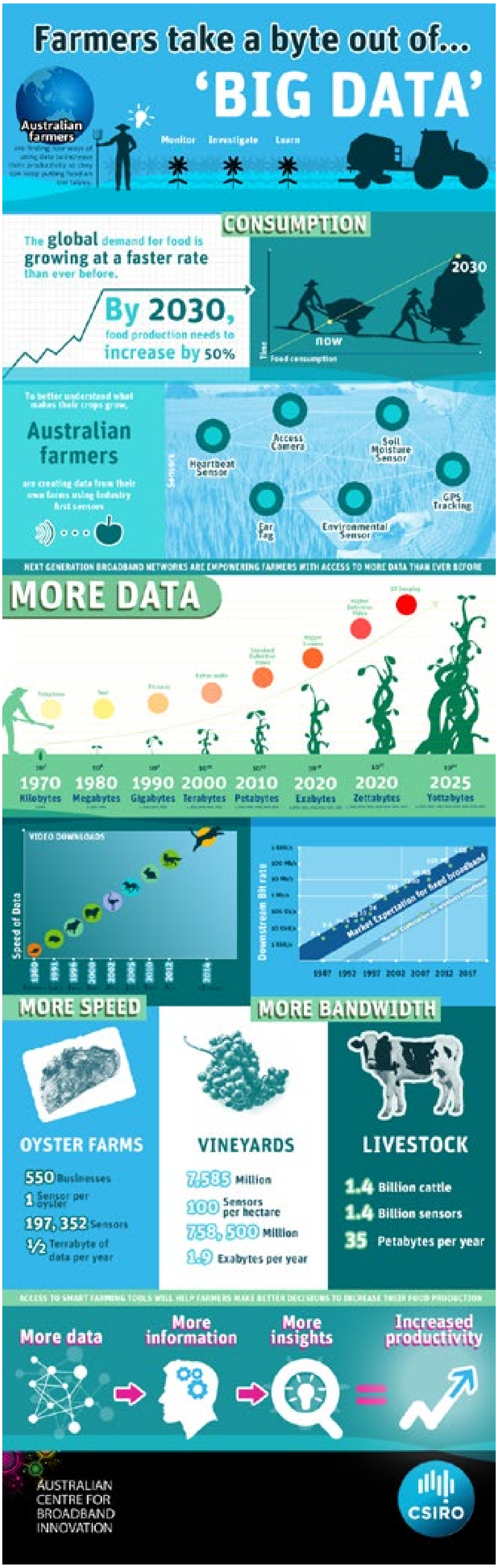
- A 'Digital Homestead' at CSIROs Lansdown Research Station near Townsville, Queensland, where a similar smart farm system has been developed suitable for Northern Beef enterprises. The project is integrating disparate sources of information from on-farm sensing of soils, vegetation, livestock and the environment as well as from external sources such as climate forecasts and market information, into a simple and usable cloud-based decision support systems for farmers and agriculture advisers.
- The Sense-T program based in Tasmania that is based on the challenge of how to scale individual local scale sensor networks into a state-wide federated intelligent sensor system where sensor data can be easily shared and turned into valuable services. The project will aggregate historical and spatial data with real-time sensor data from across the state, with an initial focus on agriculture and other primary industries (aquaculture, dairy beef, viticulture and irrigation). Information will be available through websites or apps to help businesses, governments and citizens better manage their resources.

These projects are exploring some of the emerging opportunities and drivers for adoption of digital services for the agricultural and related food sector, including:

- Integration of sensor data and related digital services into vertical supply chains to create efficiencies and innovation in processing, distribution and marketing.
- The increasing focus by agribusiness companies on using digital services to optimise supply chains and complement their traditional focus on physical products and processes.
- Biosecurity and food safety initiatives that will increasingly use agricultural sensor data for early detection and monitoring of incidents.
- Growing consumer demand for information about food provenance that can be used to add value to food and provide more customer choice.
- The development of tools and methodologies for biomass and carbon accounting that can be used for farm operations as well as emerging carbon markets.
- Addressing the unmet demand from rural communities for better access to education, health and other social and communication services.

Through the Kirby Smart Farm and related CSIRO supported smart farming initiatives and associated research we can start to estimate the potential benefits for Australian farming enterprises from broadband and digital services.   Initial reports on smart farming productivity benefits indicate significant benefits for soil fertility improvements, feed allocation, animal production and animal health monitoring.

It is proposed that although benefits from innovation created through digital services will accrue at farm level, there is untapped benefit to be obtained at the industry scale. These benefits will be driven by sensor and software services supported by ubiquitous broadband and cloud computing capabilities which will be able to aggregate farm-level and other data for industry-scale optimisation.



Farmers take a byte out of...
'BIG DATA'
Australian farmers
Monitor
Investigate
Learn
CONSUMPTION
The global demand for food is growing at a faster rate than ever before.
By 2030, food production needs to increase by 50%
2030
now
Time
Food consumption
To better understand what makes their crops grow,
Australian farmers
are creating data from their own farms using industry first sensors
Sensors
Heartbeat Sensor
Access Camera
Soil Moisture Sensor
GPS Tracking
Ear Tag
Environmental Sensor
NEXT GENERATION BROADBAND NETWORKS ARE EMPOWERING FARMERS WITH ACCESS TO MORE DATA THAN EVER BEFORE
MORE DATA
1970 Kilobytes
1980 Megabytes
1990 Gigabytes
2000 Terabytes
2010 Petabytes
2020 Exabytes
2020 Zettabytes
2025 Yottabytes
VIDEO DOWNLOADS
Speed of Data
Downstream Bit rate
Market Expectation for fixed broadband
1987 1992 1997 2002 2007 2012 2017
MORE SPEED
MORE BANDWIDTH
OYSTER FARMS
550 Businesses
1 Sensor per oyster
197, 352 Sensors
½ Terrabyte of data per year
VINEYARDS
7,585 Million
100 Sensors per hectare
758, 500 Million
1.9 Exabytes per year
LIVESTOCK
1.4 Billion cattle
1.4 Billion sensors
35 Petabytes per year
ACCESS TO SMART FARMING TOOLS WILL HELP FARMERS MAKE BETTER DECISIONS TO INCREASE THEIR FOOD PRODUCTION
More data
More information
More insights
Increased productivity
AUSTRALIAN CENTRE FOR BROADBAND INNOVATION
CSIRO

1. Background

1.1 Australian Farms

The Australian rural sector have a long and proud tradition of innovation. It has helped pioneer new tools and techniques that have made Australian primary industries highly productive and competitive. The rural sector also makes a broader contribution to the broader Australian economy.

While agriculture contributes about 3% to Australia's GDP, with the inclusion of all value-adding industries such as food and fibre processing as well as related input industries such as agriculture services, the broader agribusiness sector contributes about 12% to Australia's GDP.[1]

Australia's agricultural and upstream service and processing industries face a range of new challenges and opportunities. As over 60% of Australia's agricultural output is exported, our absolute advantage in production costs is critical as Australian farmers are usually price-takers in the world market.

Productivity growth in the agricultural industry has remained fairly static over the last few decades (about 1.6% pa), albeit with higher growth in the 1970s and 1990s and a decline in growth in the early 2000s. In general, the industry's productivity levels have been below that of major competitor countries such as the United States and Canada.[2]

Australian farmers have experienced a range of challenges including the impact of drought and weather, decline in the terms of trade for key commodities and the high level of the Australian dollar. Other challenges include the need to adopt more environmentally sustainable farming practices to either maintain and increase their output, the impact of an ageing workforce and difficulties in attracting the next generation of talent to join the industry.

These challenges are set against the dramatic projected growth in demand for food over coming decades and associated opportunities for Australia to increase its exports in agriculture and food products.

The National Food Plan reports on the growing global demand for food with the value of world food consumption projected to be 75 per cent higher in 2050 than in 2007, with the increase most strong in Asia, doubling between 2007 and 2050. The Plan also sets the goal for 2025 that the "value of Australia's agriculture and food-related exports will have increased by 45 per cent (in real terms), contributing to an increase in our gross domestic product". The Plan also notes that this increase in demand and rise in Australian agribusiness exports will not necessarily flow through into higher prices for agricultural products.[3]

This situation requires that Australia's rural sector must make a step change in its productivity to both help realise these economic opportunities as well as be more environmentally sustainable. CSIRO's Sustainable Agriculture Flagship has set a national goal of helping "to secure Australian agricultural and forestry industries by increasing productivity by 50 per cent and reducing net carbon emissions per unit of food and fibre by at least 50 per cent between now and 2030".[4]

1 National Farmers Federation, Farm Facts 2012, http://www.nff.org.au/farm-facts.html (accessed 20 June 2013)
2 Rural Industries Research and Development Corporation, Cross-country Comparisons of Agricultural Productivity: An Australian perspective, March 2013, pp. 4-15. https://rirdc.infoservices.com.au/items/13-011 (accessed 20 June 2013)
3 National Food Plan: Our Food Future, Department of Agriculture, Fisheries and Forestry, Canberra. Australian Government, 2013. http://www.daff.gov.au/nationalfoodplan/white-paper (accessed 20 June 2013)
4 CSIRO Sustainable Agriculture Flagship, CSIRO http://www.csiro.au/en/Organisation-Structure/Flagships/Sustainable-Agriculture-Flagship/SAF-overview.aspx (accessed 20 June 2013)

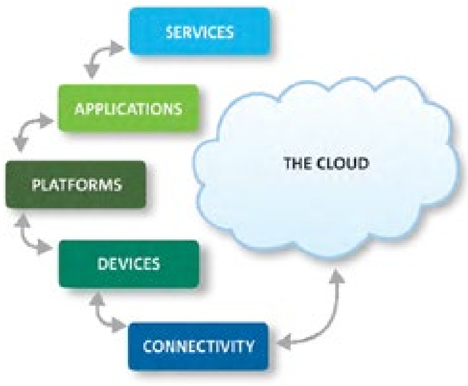
1.2 Technology and Smart Farming

While the use of computing and telecommunications technologies have been used in the rural sector for the last two decades, its adoption has been uneven and its full potential unrealised.

During the 1990s, the practise of precision agriculture was adopted by parts of the Australian agricultural sector. One of the big drivers for precision agriculture was the availability of satellite based information. The use of Global Positioning System (GPS) has been a major contributor to improvements in the use of farm equipment for cropping industries while the use of satellite imagery has contributed to improved knowledge of soil and vegetation conditions at a large scale level.

Terrestrial sensor systems have been used to provide more detailed information about local soil, vegetation and water conditions. These systems have been used as a periodic planning and prediction tool, testing conditions to assist with the application of fertilisers, planning of crops and stocking levels, and release of water flows for irrigation. Where sensors have been used to provide real-time monitoring of local conditions, these systems have generally been high cost and hence limited in deployment and mostly used for a single purpose.

While Australian farmers have generally shown strong interest in new telecommunications services, their adoption has tended to lag other industries. A recent ACMA report noted while that most Australia farmers had a landline connection (99%), the use of mobiles was much lower at 85% compared to the general use in Australia.[5] Recent surveys have also reported that while larger Australian agricultural enterprises have a high level of internet adoption (about 90%), there is much lower rate of connection for smaller farming enterprises (about 70%), a lower use of broadband internet connections in general.[6]



Access to timely information over the internet has become an essential tool for Australian farmers. This includes accessing weather, market prices and general advisory information on products, equipment and techniques. It has also become a vital for social communication as well as accessing a range of business, government, education and health information.[7]

1.3 Impact of Next Generation Network Broadband

There are new opportunities emerging for the rural sector to improve its level of productivity and develop new markets. These opportunities are being created by the rollout of a next generation network broadband across the continent and through the growing impact of the digital economy on all sectors of the Australian economy.

While Australian farm enterprises and related agricultural service industries traditionally show strong interest in new telecommunications and computer services, their adoption has been variable due to a number of factors including lack of universal availability, cost, capability and lack of maturity and reliability of the services being offered. For example, there is a higher pent up demand for improved mobile and fixed broadband services from farmers compared to other sectors of the Australian economy and on average users in outer regional and remote areas have a 10% lower use of the internet compared to the rest of Australia.[8]

5 Australian Communications and Media Authority, Report 3: Farming sector attitudes to take-up and use, and Report 4: Consumer Satisfaction, in Telecommunications Today series, 2008.
6 ABS, Report 8150.0 - Use of the Internet on Farms, Australia, 2007-08 and ABS 8129.0 - Business Use of Information Technology, 2011-12.
7 Department of Agriculture, Fisheries and Forestry (December 2005), Young Farmers' Information Needs, research conducted by Kondinin Group.
8 ABS, 8146.0 - Household Use of Information Technology, Australia, 2010-11.

Australia's national broadband infrastructure will potentially change this situation, with rural Australia to receive greatly improved access to high capacity broadband services based on uniform wholesale prices and universal national coverage. These services will include mostly fixed broadband satellite and terrestrial wireless services but may include some optic fibre services.

The significance of this development is that these improved broadband services will be complemented by a confluence of a number of equally important developments with related technologies. These include:

- Sensor technology systems that are increasingly low cost and ubiquitous creating an "internet of things" where a growing number of "things" such as pasture vegetation, soil moisture, livestock movements and farm equipment can be monitored;
- The availability of spatially-enabled, mobile sensing technologies for characterising farmscapes (eg identifying soil groups) and measuring changes in biomass;
- Local wireless systems that make it easier to connect this "network of things" to fixed broadband networks thus creating an "internet of things";
- Smart personal devices that make accessing information on the move easier and the development of easy to use and fit-for-purpose apps;
- Cloud computing technology that simplifies access to and sharing of information and applications removing many of the requirement for on-farm computing systems;
- Increasing ease of use of video-conferencing systems that are personal and can be used in the field through low cost personal devices or dedicated video monitoring services.

1.4 Transformation through the Digital Economy

The increasing availability and adoption of these technologies and systems are driving the emergence of a digital economy across all sectors of the Australian economy. The digital economy is "the global network of economic and social activities that are enabled by platforms such as the internet, mobile and sensor networks" which has the potential to transform many of Australia's industries.[9]

Various studies have modelled the contribution of the digital economy to the growth of the national economy and improvements to industry productivity. A report by Deloitte Access Economics estimates that the digital economy contributes $27 billion in productivity benefits to Australian businesses and government organisations.[10] IBIS World estimates that through the impact of the digital economy, Australia will return back to its long term productivity growth rate of to 1.7% per annum by 2020.[11]

The interesting question is what will be the impact of broadband and the digital economy on Australia's rural sector? There have been some industries such as publishing, music and travel sectors where the impact has been extremely dramatic. These industries have been more susceptible to transformation due to the ease of digitising key parts of their products and processes.

The impact of broadband and the digital economy could be equally dramatic over time for other industries that might appear less susceptible to digitisation. The rollout of broadband and sensor networks, accompanied by new information services, could not only transform the practice of agricultural industries but also the relationships with upstream service, food processing, logistics and retail industries.

9 Australia Government, Digital Economy: Future Directions, July 2009, p.2. http://www.dbcde.gov.au/digital_economy/what_is_the_digital_economy (accessed 20 June 2013)

10 Deloitte Access Economics, The Connected Continent: How the internet is transforming the Australian economy, August 2011. http://www.deloitte.com/assets/DcomAustralia/Local%20Assets/Documents/Services/Corporate%20Finance/Access%20Economics/Deloitte_The_Connected_Continent_Aug_2011.pdf (accessed 20 June 2013)

11 IBIS World, A Snapshot of Australia's Digital Future to 2050, June 2012. www.ibm.com/au/pdf/1206_AustDigitalFuture_A4_FINALonline.pdf (accessed 20 June 2013)

2. Kirby Smart Farm

2.1 Introduction

CSIRO and the University of New England have set up a demonstration Smart Farm in Armidale, NSW to investigate and demonstrate the impact of broadband and related digital services for Australia's rural sector. The initiative is lead by the Australian Centre for Broadband Innovation (ACBI), a collaborative research initiative established by CSIRO, and UNE's Precision Agriculture Research Group.

The Kirby Smart Farm is a 2800 hectare working commercial farm located 10 kilometres north-west of UNE's campus at Armidale. The farm focuses on merino wool and beef cattle but various grains for livestock feed are also produced. At Kirby, the pasture is a mixture of native grasses, introduced clovers and developed rye-grass and fescue-based mixtures. Productivity on a farm of this kind is highly dependent on pasture management because it provides the main food source for the livestock.

The farm was one of the first mainland farms connected to the NBN terrestrial wireless broadband service (initially at 12 Mbps downstream and 1 Mbps upstream with a planned future upgrade to 25 Mbps downstream and 5 Mbps upstream).

Through this project, CSIRO and UNE have developed a flexible platform to support future smart farming applications and services. The concept of the Smart Farm was that digital services will allow farmers to deploy resources more efficiently, remotely monitor everything from soil moisture levels, stock movements and farm security, as well as easily and instantly communicate with experts on everything from a broken tractor to commodity prices.

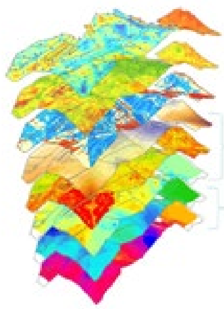
Many of the features of the Kirby Smart Farm are also being explored through the Queensland Digital Homestead project where similar soil, environmental and cattle tracking sensor networks have been installed complemented with an information platform to integrate disparate on-farm and external data sources.

2.2 Kirby Smart Farm services

The Smart Farm includes the following features:

Spatially-enabled, baseline dataset for farm mapping and characterisation

A comprehensive, spatially-enabled planning and management dataset was assembled based on many of the precision agriculture technologies and services available to Australian farmers. These included data derived from GPS-based asset mapping (fences, water points, on-farm infrastructure), as well as GPS-enabled electromagnetic induction (EMI) soil survey, digital elevation mapping (DEM), active, optical sensor (AOS) pasture biomass survey, contemporary and historical airborne and satellite imagery and soil chemistry via X-ray fluorescence spectroscopy (XRF).



Some of the detailed survey data from Kirby Farm used to determine soil sensors. (Image courtesy of UNE Precision Agriculture Research Group).

A live map of local soil moisture and environmental conditions

At the Kirby Smart Farm, local sensors have been deployed at Kirby to monitor soil moisture, temperature, electrical conductivity, and air temperature every five minutes to create live maps.

100 soil sensors were installed on the farm is a distributed pattern at locations that represented homogenous soil conditions. Each located node consists of a soil moisture node that measures moisture, temperature, electrical conductivity (which is correlated with salinity) and an air temperature sensor at 2.4m above ground. As well, two local weather stations

were installed to measure air temperature, humidity, and pressure, wind speed and direction, rainfall and hail, as well as solar radiation.

These sensors provide vital information that can be used to advise on when to sow crops or pastures, when to fertilise or irrigate and where and when to move livestock. This information can help farmers increase their crop and pasture yields by targeting the use of water and fertilisers and to increase stocking rates through better pasture management.

There is a growing body of evidence that spatial-based soil monitoring technology can provide significant benefits to the farmer's bottom line. For example, cotton growers using these sensors are almost doubling their yields per megalitre of water used when they vary irrigation rates according to the localised needs of the soil and plants, rather than taking the one-size-fits-all approach for a whole field.

All of the sensors were based on commercial sensor systems integrated into either the soil sensor nodes or the local weather station nodes. Both of these nodes were assembled and deployed at a cost of just under $1,000 per unit. It is expected that the cost of such nodes could be reduced to several hundred dollars with larger production runs and growing the local capability to deploy more easily.

Understanding livestock activity

The Armidale Smart Farm project is also investigating the use of low cost wireless cattle tracking systems to improve livestock management. The project has used a commercial cattle tracking sensor developed by Taggle, an Australian technology company. The Taggle sensor is a low-powered ear tag that can track an animal's position with a range of approximately 7kms from with an accuracy of plus or minus 15 metres.

The Taggle system can be used to provide the real-time location of livestock as a map-based interface for a mobile smart device or desktop website. It can also be used to send SMS alerts when livestock move outside of a pre-determined area (eg move into another paddock or a possibly stolen). The project is also investigating the ability to generate alerts that provide an indication of grazing habits, animal attacks and calving.

The Armidale Smart Farm has also been using CSIRO developed cattle tracking technology that incorporates accelerometers and GPS devices that can provide more fine detailed information about livestock movement and behaviour.

It is expected that data from the wireless cattle tracking systems, such as those deployed on the Kirby Smart Farm and Queensland Digital Homestead projects, will increasingly be able to provide analysis of the pasture productivity, locating which parts of a paddock are highly productive versus areas that could be targeted for improvement. This data could then be used to optimise the location of feeding and watering points. There is also the opportunity to link cattle tracking and activity data to the

NLIS animal identification system to assist with herd management and breeding.

Wireless livestock tracking using Taggle ear tags (Image courtesy of AgTrix P/L website; inset image courtest of Mark Trotter, UNE Precision Agriculture Research Group)

Local wireless networks

Local wireless networks allow the fixed and mobile sensors to send a continuous stream of data to a remote cloud based computing and analytic service.

The soil sensors use an ad-hoc wireless network to send a signal back to a central collection point located in a farm building. From this point, the data can be sent either by an NBN or mobile data link back to a cloud computing service.[12]

The cattle tracking sensors also use a local wide area wireless network operated by Taggle, the service provider of the sensors.

12 The sensor nodes form a wireless multihop network, which allows them to communicate back to a Linux gateway located in the farm's shearing shed where recent data feeds are stored to files. The data is regularly pushed to an instance of the open source GSN stream processing middleware.

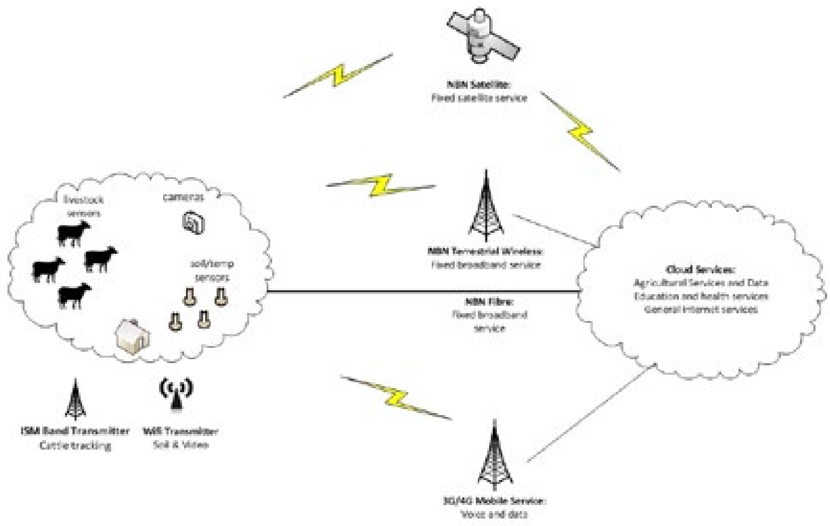
The cattle tag sends data one-way via a local wireless network managed by Taggle back to a central cloud server. The wireless system requires a number of transmitters as an animal's position determined by triangulation of the data sent from the cattle tags. This network interconnects into the public telecommunications network in Armidale.

The Smart Farm Information Platform

A Smart Farm Information Platform has also been developed for the Kirby Farm project. This platform seamlessly brings many different data sources together in a user-friendly and practical way. These data sources include the on-farm sensor data from the soil and livestock nodes as well as off-farm data such as weather and water information. The Information Platform displays through a web browser the information gathered by the varied technologies on an aerial map view of the property so the farmer can see each sensor and instantly access the collected information.

This information is presented in easily understandable and practical ways to give a real-time picture of everything from the farm's soil conditions to stock disposition at any given moment. Once established, valuable support tools can be added to the portal, such as automatic text message alerts notifying if something is wrong or when conditions are optimal for sowing or moving livestock.

The Smart Farm Information Platform can collate the sensor data from the temperature, wind, solar radiation, humidity and livestock sensors to generate a map of Comprehensive Climate Index (CCI) and Heat Load Index (HLI) across the farm. These indices can be used to indicate animal wellbeing and potentially send alerts outside of a threshold range.

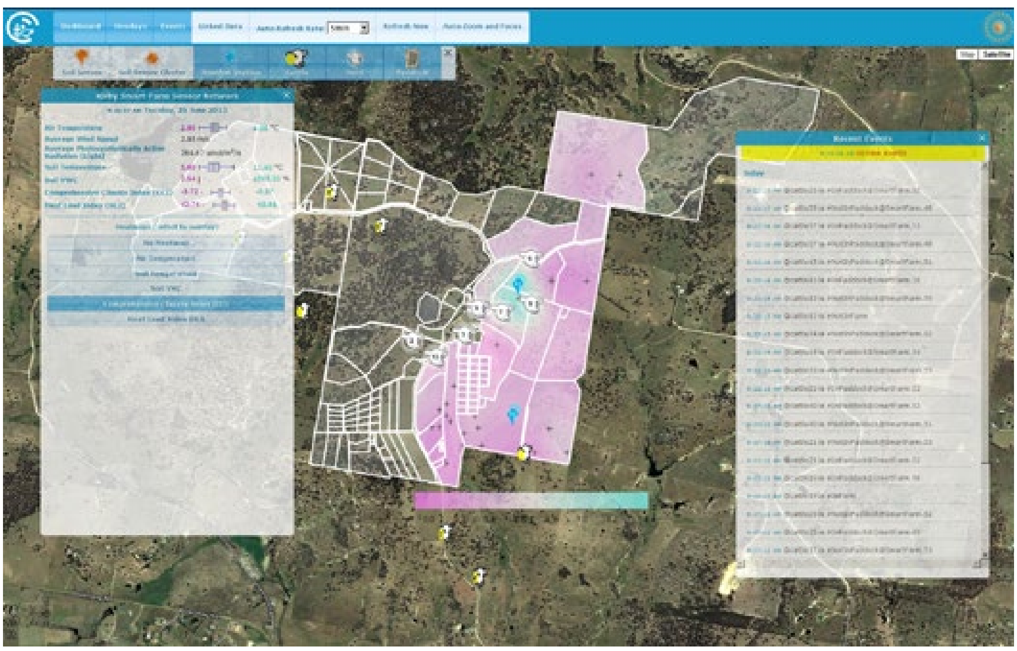


Local wireless network connected to the NBN

Armidale Smart Farm Information Platform

The Smart Farm Information Platform can be described as a Decision Support System(DSS) which are used to assist farmers and other users make decisions about farm management. The Platform consists of the following features:

- **Sensor Streaming Middleware:** This is a cloud-based computing service that can collect and process sensor data and then send it to an application such as web display portal. The Smart Farm Information Platform uses an open source middleware software called Global Sensor Network (GSN). Other commercial middleware software systems could be used as alternatives.



Armidale Smart Farm Information Platform

- **Semantic Web Interface:**
  This is a software system that allows conceptual queries to collect, integrate and present disparate data sources back to a person. This means that a person can ask a question about adverse weather conditions, best time to sow or cattle grazing patterns based on historic and current data. Such systems provide the potential to be more flexible than traditional DSS where the ability to interrogate disparate data sources is often limited.
- **Web display portal:**
  This is a web-based service that presents the sensor and related data in a variety of ways to the user. This includes presenting the data as text based alerts, location based data as points or overlays on a map and detailed tables of data. The location based data can present location of livestock and overlays showing temperature, soil moisture and management indices such as the CCI and HLI.
- **Open linked data:**
  The farm data is also routinely aggregated, packaged and published to the web in a format (called a data cube) for reuse in mashups and research studies. The internet information platform also provides access to queries over this data combined and compared with the growing resources of the public Semantic Web.

Recent studies of agricultural DSS applications have found that successful systems should aim to educate and enhance farmers' intuition and enable users to experiment with options that satisfy their needs rather than replace their knowledge with optimised recommendations. The Smart Farm Information Platform has been designed to do this, allowing the farmer to specify and experiment with their own alerts.[13]

Portable and in-field video camera and conferencing systems

While the use of digital camera technology on farms is already being used for security, the availability of high speed broadband access has the potential to take the uses of imaging to a whole new level.

Future developments proposed for the Smart Farm include the use of miniature headset cameras connected to local wireless networks to allow farmers to remotely troubleshoot machinery problems with their local mechanic or diagnose animal health problems with their local vet.

Other developments proposed include the installation of a number of 360 degree cameras to observe cattle at locations where they congregate, such as around water troughs. Utilising both video and still images, it is proposed to develop algorithms to analyse the captured footage of stock with the aim of integrating them with data such as stock ID, weight information and environmental data.

The Smart Farmhouse services

As any farmer knows, farming isn't just a business, it's also a lifestyle. The Kirby Smart farm will have a Smart Farmhouse designed to demonstrate all the benefits that broadband connectivity can bring to families at work or play. High definition video conferencing and other broadband enabled applications offer pathways for business support, on-the- job training, remote health and education services and entertainment and social networking.

The Smart Farmhouse will also be set up as a connected classroom where students of all ages and community groups can access the latest data streaming from a range of field, animal and machinery sensors, and participate in 'virtual' field days.

13 Hochman and Carberry (2011)

3. Other CSIRO Smart Farming Initiatives

3.1 Queensland Digital Homestead project

A 'Digital Homestead' at CSIROs Lansdown Research Station near Townsville, Queensland, where a similar system relevant to Northern Beef enterprises is being developed. This project will integrate multiple disparate sources of information from on-farm sensing of soils, vegetation, livestock and the environment as well as from external sources such as climate forecasts and market information into a simple and usable cloud-based decision support systems for farmers and agriculture advisers. The project collaborators include Queensland Department of Agriculture, Forestry and Fishing, James Cook University and Queensland University of Technology, co-funded by Queensland Government Smart Futures fund.

The project focus is on building a 'dashboard' that integrates and presents the information in such a way that better (more informed, accurate, more timely, and/or more risk-aware) decisions can be made. The dashboard has been designed so it can be tailored to the individual needs and preferences of end-users.

The additional opportunity is to build new and adapted businesses in the service sector, and across the value chain, that can be delivered virtually, taking advantage of the 2-way real-time connectivity of the system.

This is part of a broader effort in CSIRO's Sustainable Agriculture Flagship which is developing technologies that communicate in risk and certainty and reduce the challenge that land managers and their advisors face in integrating and interpreting multiple disparate sources of information. Use of these technologies will drive outcomes in profit, productivity and sustainability as risk and consequence of options in our most complex systems become more accessible. These new technologies will form the backbone of emerging agribusiness service enterprises linking data and translating it into insight.

Townsville Digital Homestead – Cattle tags

3.2 Tasmanian Sense-T program

The Sense-T program based in Tasmania which is based on the challenge of how to scale individual local scale sensor networks into a state-wide federated intelligent sensor system where sensor data can be shared and turned into valuable services. The project will aggregate historical and spatial data with real-time sensor data from across the state, with an initial focus on agriculture and other primary industries. Information will be available through websites or apps to help businesses, governments and citizens better manage their resources. The project partners include CSIRO, University of Tasmania, Tasmanian Government and IBM.

As the projects mature, Sense-T will address the commercial business models for the ecosystem of sensors, networks, data analytics, market segments and applications/services that will combine to provide a sustainable market for information and applications leveraging sensor data.

Tasmania will be the most sensed environment over the course of the program and it is expected that major services and business models will be exported from Tasmania to both other domestic programs in Australia and internationally.

The initial Sense-T projects include:

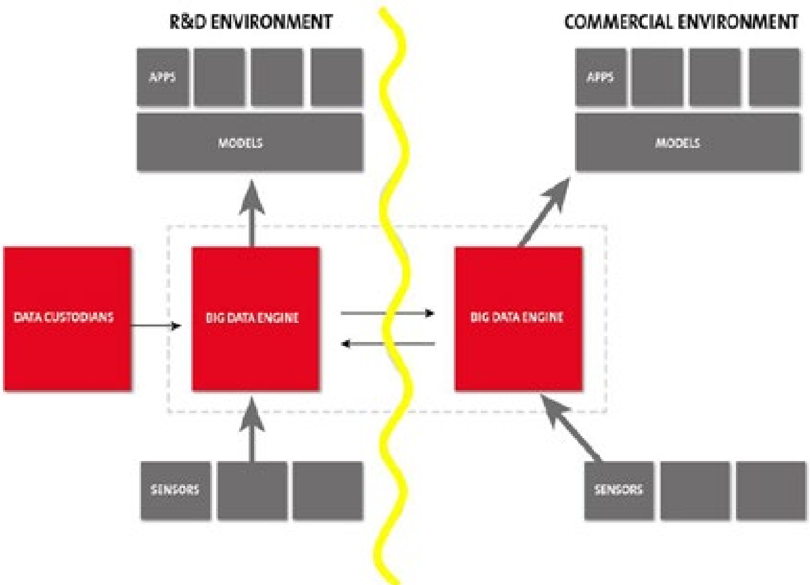
Aquaculture industries

Working with the oyster, salmon and abalone farming industries, Sense-T has combined biosensors with environmental sensors to improve competitiveness and environmental performance. A major driver is to improve animal wellbeing, reduce costs, optimize harvesting and demonstrate continued high-levels of food safety. The focus will be on the Huon, East Coast and Circular Head regions.

Pasture optimisation and decision support tools for the dairy and beef industries

This project is developing web-based tools for farmers that draw on local sensors and historical data for localised prediction of pasture growth, and is also testing new technologies for tracking cattle behaviour with the aim of improving the early detection of subclinical diseases, reproductive performance and feed allocation. The information is delivered through decision support systems (DSS) that link biophysical data with input/output price scenarios that will assist farmers to make more informed management decisions.

Sense-T technology architecture



Disease Detection for Grape Growers

This project will use sensor technology to help build the capacity of grape growers to detect diseases such as Botrytis bunch rot in their crops. This help them to achieve greater consistently supply high quality product through access to timely and reliable information to support decisions. The alerting component will deliver risk model outputs and configured alerts from integrated sensor resources.

Adaptive water resources management for irrigation and environmental protection

In this project real-time monitoring and prediction of stream flow and other environmental indicators in two adjacent, contrasting catchments in Northern Tasmania will be linked to scheduling of water extractions and releases by irrigators. A major output for farmers, water regulators, and other stakeholders will be a user-tailored online 'dashboard' of real-time information that can assist decision-making on water management.

Pathways to Market initiative, which will employ new sensor technologies that can track food from paddock to plate. The project involves data management in three key areas: food stability, traceability and logistics; environmental impact; and effect of production location on consumer choice. The choices that consumers make can then be fed back to producers, helping them to better understand market behaviour.

All these existing Sense-T projects will deliver value into their respective market sectors but even more valuable may be the future links that enable information to flow across industry sectors. It is foreseen for example, that agricultural activities on land will eventually provide useful information to Aquaculture activities in the adjacent water ways and vice versa. These sorts of future digital economy outcomes may not yet be well understood however as the understanding of the overall ecological effects emerge then Sense-T will be at the forefront of the opportunity to leverage these benefits in the export of new services and business models.

4. Drivers and Barriers for Changes

4.1 Drivers for Change

There are also some broader drivers for the adoption of Smart farming and new digital services for the agricultural sector, including:

Integration into vertical supply chains: One of the success factors in driving adoption of digital services has been where a key operator in the agriculture supply sector requires their suppliers/producers to use a specific software service to optimise their operations (eg the Agtrix software has been widely adopted in the sugar cane industry led by mill operators requiring growers to use the system to schedule harvesting and milling).[14]

Shift by agricultural suppliers from products to service: As exemplified in other industries, many of the larger manufacturers and suppliers of agricultural products are facing reduced margins on the supply of physical goods and are directing their business strategies towards providing services enabled by digital technology. For example, large fertiliser companies are looking to increasingly supply advisory services as opposed to just fertiliser products while farm equipment companies are providing advisory services for precision agriculture in addition to farm machinery.[15]

Biosecurity and food safety initiatives: The threat of disease outbreaks such as Foot and Mouth Disease has led government and industry regulators to introduce the National Livestock Identification System (NLIS) to track and trace cattle across Australia. The implementation of smart farm sensor services can extend the value and timeliness of livestock information to assist with the response to threats and outbreaks of disease and more managing animal health more generally.[16]

Open data policies and practices: There has been a strong push for government agencies to make their data available for reuse through open licensing frameworks such as Creative Commons and Open Database Licence. This approach to open data and the value of sharing has been strongly supported by government agencies responsible environmental and natural resource data that is most useful for agricultural decision support systems.

Biomass and Carbon Accounting: The development of tools and methodologies for biomass and carbon accounting can be used for farm operations as well as emerging carbon markets. For example, a combination of fixed and portable scanners could measure biomass for farms and tree plantations and these could be used to give more accurate farm based data on carbon accounting compared to more generalised models.

Consumer demand for food provenance and choice: There is growing consumer demand for more information about the conditions under which food is produced and marketing companies are seeking to exploit this interest to create value-added brands. For example, Cape Grim Beef supplies premium beef internationally using local sensor data to verify the "clean and green" environmental conditions on the farm.[17]

Cost of sensors and sensor networks: Sensor technology is becoming increasingly commoditised driven by the increasing demand for a wide range of industrial, research and domestic applications. This will drive down the cost of sensors as the number of manufacturers and suppliers increase.

14 See Case Studies on Agtrix website, http://www.agtrix.com/case-studies (accessed 18 June 2013)
15 Louise Lucas and James Shotter (2012). "Syngenta nurtures seed-to-harvest model", Financial Times, December 12 2012 and Fang, E., Palmatier, R., & Steenkamp, J. (2008). Effect of Service Transition Strategies on Firm Value, Journal of Marketing, 72:1–14
16 National Livestock Identification System Database, Meat & Livestock Australia Limited , https://www.nlis.mla.com.au/ (accessed 20 June 2013)
17 Cape Grim Beef , http://www.capegrimbeef.com.au/ (accessed 20 June 2013)/

Availability of low cost and agile cloud services:
Led by the larger internet companies like Amazon, Google and Microsoft, cloud technology has become available at low cost for software developers to run computing services in an agile and rapid manner. For the farmer, having data captured, processed and analysed remotely through cloud services, makes it easier to install and use digital services.

Rural communities' increased use of digital services:
There is interest and unmet demand from rural communities for better access to education, health and other social services as well as entertainment and social media communication.

Armidale Smart Farm – Cattle tags

4.2 Barriers to Adoption

Some of the existing barriers to adoption are being addressed in Australia through wider technology and industry developments. These include:

Detailed understanding of cost-benefits:
To date, most estimates of the cost-benefits from the adoption of smart farming in the agricultural sector has focused on specific types of farming such as cropping and irrigation based enterprises. There has been less analysis on the benefits from the broader adoption of sensor based digital services for other farming operations such as livestock operations. Further research is required to document these benefits and value propositions based on evaluation of the use of smart farming systems, showing what the benefits are at farm enterprise level as well as to broader supply chains.

Level and quality of connectivity:
While rural areas are increasingly connected to a variety of telecommunications systems including 3G and 4G (LTE) mobile services as well fixed broadband data services from the NBN, there are still major gaps in coverage. For example, while mobile phone networks cover up to 99% of Australia's population they cover significantly less of the landmass. Also, the NBN currently only provides connections to premises such as homes and offices so their fixed broadband services are not available for non-premise locations that could require services on farms.

Adoption of standards for sensor networks and data:
The development and widespread adoption of standards for data management and exchange have made it easier to develop reusable and extensible software platforms for smart farm services. The W3C developed an ontology for describing sensor networks in 2011 and has started a group for livestock data interchange in 2013. Also, the adoption of standard ways to connect sensors together will make it easier to install, manage and support sensor systems.

User acceptance:
As highlighted above, DSS need to be designed to support and extend farmers' capabilities rather than replace and be able to be adopted by a support network of service providers and other business in the support network and supply-chain connected to agriculture. Further work needs to be done to understand user needs and capabilities.

Maturity of software and services industry for agricultural applications:
A recent survey of agriculture software suppliers in Australia highlighted the large number of small scale software companies, most of which lack scale, scope and maturity of business operations to drive more rapid adoption.[18] In order to grow the software and services industry for agricultural applications, it will need to achieve greater scale through consolidation, investment and maturity of service offerings.

18 (RIRCD, 2007)

5. Realising the Benefits

5.1 On-farm benefits

Through the ACBI Smart Farm and related smart farming initiatives and associated research we can start to estimate the potential benefits for Australian farming enterprises from broadband and digital services.

A recent report from Meat & Livestock Australia (2012)[19] identified four areas of greatest potential benefit from the use of digital technologies for beef and sheep livestock enterprises, these being:

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

The report estimates productivity benefits from improvements in farming activities, based selected case studies, as 13-26% for soil fertility improvements, 9-11% for better feed allocation, 4-9% for animal production monitoring and 4-13% for animal health monitoring.[20] These preliminary findings need to be tested through the evaluation of larger deployments of such improvements supported by smart farming technology with a range of different agricultural industries so that more accurate aggregate estimate of productivity benefits can be measured.

Other reports from different agricultural industries have identified similar positive productivity benefits from the adoption of smart farming. Most of these studies have concentration on cropping and irrigation industries, where the adoption of precision agricultural equipment and services has been the strongest.

Further research is required to document the benefits from the use of smart farming systems, showing what the benefits are for individual farmers in a variety of farming operations. Ultimately, the broader challenge for smart farming is to understand what contribution it might make to increasing overall productivity for Australian agriculture.

5.2 Broader economic opportunities

The other benefits to be realised for Australia's agribusiness sector is the creation of new economic opportunities through the development of new markets and ways to value add to its farming produce. As the recent Asian Century Report and National Food Plan have highlighted, there are major opportunities for Australian agriculture and food sectors to not only increase their production, but also drive innovation and create new export markets.[21]

This indicates that value-adding to Australia's exports will also be essential in order to raise incomes for Australia's agricultural and food industries. The National Food Plan states that "our aim is that Australian food is the food of choice globally—renowned for its quality and consistency, valued for its safety and sustainable production, and attracting premium prices—whether staple foods like wheat or sugar or luxury items like lobsters and premium wines."[22] The information generated through smart farming sensor systems that can help provide the provenance about such quality

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19 Potential for information technologies to improve decision making for the southern livestock industries, Meat and Livestock Corporation, 2012, p. 5.

20 Potential for information technologies to improve decision making for the southern livestock industries, Meat and Livestock Corporation, 2012, pp. 86-93. The report evaluated the growth in Total Factor Productivity (TFP) due to the application of precision technology in each key decision area.

21 Australia in the Asian Century White Paper, Australian Government, 2013. http://asiancentury.dpmc.gov.au/white-paper

22 National Food Plan: Our Food Future, Department of Agriculture, Fisheries and Forestry, Canberra. Australian Government, 2013, pp. 6-7. http://www.daff.gov.au/nationalfoodplan/white-paper

and consistency, thus helping enable such claims for premium products and prices.

The Sense-T program has been scoped to explore the new business models derived from the use of sensor data by industries that process, distribute and market agricultural and food products. The results from this program will help provide the evidence base and sustainable development models for the broader Australian industry.

5.3 Agribusiness Service Sector

A further benefit could be realised through the development of an agribusiness services sector supporting the agricultural and food industries through the use of digital services enabled by broadband connectivity. Just as the mining boom has created a vibrant and export orientated mining services sector, a similar opportunity could be created for the agriculture and food service industries.

This opportunity is described in the National Food Plan as "we need to move beyond just selling food to marketing our expertise in agricultural innovation and research, water and land use management, capitalising on our ability to grow food in some of the world's most difficult conditions".[23]

Economic value can be realised from data sharing via Web technologies[24]. In particular, linked data enables web users to build bidirectional connections among online data and the data can be a critical enabler for existing infrastructure in business and government as well as creation of additional value add services by small enterprises.

5.4 Environmental Management

The availability of increased information from on-farm sensors complemented by other regional based sensor data such as weather, stream flow, water tables, aerial and satellite data will also enable greater capacity for environmental management. At the on-farm level, this may include reduced use of fertilisers and associated run-offs or more efficient use of water, whereas at a regional level this could assist with better management of water resources, native vegetation and animal welfare.

5.5 Broader Social Benefits

Finally, perhaps the most important immediate benefit from broadband and digital services for the rural sector could be through improvements to the quality of life. This will be through the increased access to health, education, government and business services and thus removing some of the disadvantage from rural communities. This could help address the significant gap in general and mental health experienced in rural Australia compared to the rest of the population.

23 National Food Plan: Our Food Future, Department of Agriculture, Fisheries and Forestry, Canberra. Australian Government, 2013, pp. 6-7. http://www.daff.gov.au/nationalfoodplan/white-paper

24 Michalis Vafopoulos, The Web Economy: Goods, Users, Models, and Policies, Foundations and Trends in Web Science Vol. 3, Nos. 1–2 (2011) 1–136

Appendix A
Details about the Kirby Farm

http://smartfarm-ict.it.csiro.au/

Our prototypical smart farm, Kirby Farm, is located on a 171.3 ha livestock farming site, typical of the agriculture industry in a large area of inland eastern Australia. The farm focuses on merino wool, but beef cattle and various grains for livestock feed are also produced. Productivity on a farm of this kind is highly dependent on pasture management because it provides the main food source for the livestock. In Kirby it is a mixture of native grasses, introduced clovers and developed rye-grass and fescue-based mixtures. We performed a preliminary survey comprising an electro-magnetic (EM) soil scan, location aware digital elevation (dGPS) mapping, and a pasture biomass active optical sensor (AOS) survey, and corresponding spatial clustering analysis. This was used to place 100 soil sensor nodes, each representing a locality of approximate homogeneity, and also two above-ground weather station nodes.

Each soil node has a Decagon 5TE soil moisture sensor buried at a depth of 0.20 m measuring moisture, temperature, electrical conductivity (ECa, which is correlated with salinity, soil moisture, and clay), and an Apogee ST-100 air temperature sensor at 2.4m above ground. The Vaisala WXT520 weather stations measure air temperature, humidity, and pressure, wind speed and direction, rainfall and hail.

Collocated on the weather station nodes are Apogee SP-110 total solar radiation sensors. All nodes are Powercom Fleck 3Bs powered by solar panels with built-in sensors for solar voltage, solar current, battery voltage and battery current.

The sensor nodes form a wireless multihop network, which allows them to communicate back to a Linux gateway located in the farm's shearing shed where recent data feeds are stored to files. The data is regularly pushed into a conventional Oracle database and can be viewed at http://www.sensornets.csiro.au/deployments/684. It is also pushed to an instance of the open source GSN stream processing middleware (Aberer et al 2011).

GSN is fed with the sensor data collected from the farm. Virtual sensors of GSN are used to provide enhanced streaming output for further processing. Through virtual sensors, all data is (i) translated to RDF and persisted in a Virtuoso triple store, (ii) various algorithms implemented in Java or R are deployed that consume real-time sensor data and produce value-added streams, and (iii) semantic event descriptions are processed to generate alerts when a description is satisfied. The smart farm control portal allows a farmer to develop personalised event descriptions in terms of an ontology designed for the farm, and to respond to alerts when they occur.

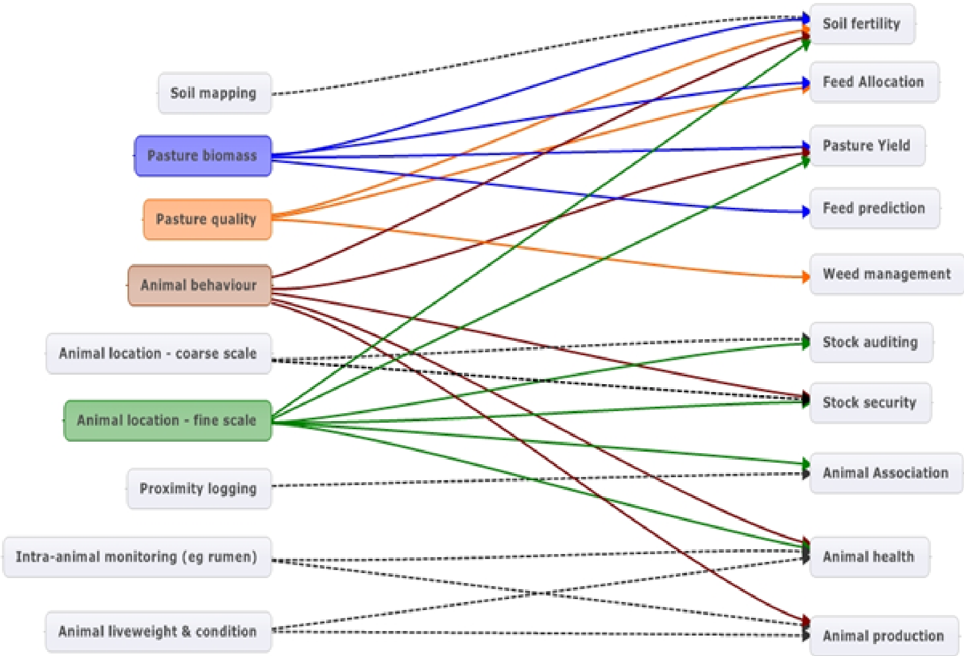
The descriptions are composed and handled via the method of Taylor and Leidinger (2011)-. When an alert is fired, the portal assembles a range of contextual information, drawn from the triple store and external linked data, to support the farmer's response to the alert.

The publication of data like this creates an opportunity to connect Web of Things agriculture data services to food processors, wholesalers, retailers and consumers for value-added benefits.

A Soil Sensor Node on Kirby farm near Armidale, NSW, Australia

Appendix B
Technologies for on-farm needs

The following diagram shows the relationship between a number of farm technology systems and on-farm needs relevant to the southern livestock industries. See *Potential for information technologies to improve decision making for the southern livestock industries* Report (M&LA, 2012).



Diagrammatic representation of how technologies (left hand side) may contribute to identified on-farm needs (right hand side). Solid coloured lines show technologies that align with 3 or more applications.

Appendix C
Research priorities

The following recommendations for R&D investment based on significant possible benefits relevant to the southern livestock industries and the potential technological solutions available, have been made to MLA from the report on *Potential for information technologies to improve decision making for the southern livestock industries* Report (M&LA, 2012)

HIGH PRIORITY

a. **Soil fertility –** The development of zone-based variable rate applications by understanding how integrated soil, plant and animal spatial datasets can best be integrated and interpreted to predict soil constraints to production.

b. **Pasture biomass –** The establishment of a regionally-based R,D&E program that simultaneously calibrates and validates a range of vehicle, airborne and satellite technologies to quantify pasture biomass, develops systems to integrate the data with farm management software, and demonstrates tangible applications in a commercial setting.

c. **Animal location and behaviour –** An investment in the development of a number of applications utilising technology to monitor the location and behaviour of animals, in particular improved feed allocation (matching animal demand with feed supply), early detection of animal health, sire-dam and dam-offspring associations, and stock auditing and security. A program of work is required to deploy these technologies and establish relationships between the location/behaviour metrics and the events of interest in order to deliver an integrated solution capable of real-time data acquisition, analysis and interpretation.

MEDIUM PRIORITY

a. **Individual animal production monitoring**

- a.1. Animal Liveweight – An investment is recommended to establish agreed data-handling processes for commercially available weighing systems (particularly walk-over-weighing) that enable producers to capture the full potential from the technology in not only mob-based but also individual animal management. This should include data infrastructure that captures information remotely and makes it readily available to producers in near real-time with appropriate integration with decision support systems.
- **a.2 Body condition score –** The current MLA investment into an imaging system for measuring p8 fat and muscularity should be supported so that its potential accuracy and reliability in on-farm conditions can be evaluated. However an investment is recommended into laser scanner technology because it actually quantifies the structure of the animal, and is less likely to be subject to errors associated with field conditions.

b. **Animal health and rumen function –** The current MLA investment into the intra-ruminal device for measuring methane needs to be fully supported, and if successful in terms of the platform technology, then it should be extended to include key rumen health (eg pH, temp) and nutritional (eg VFA) parameters. A watching brief should also be kept on commercial developments to see if issues related to device longevity can be overcome. The investment recommendation above in animal location/behaviour applications should also focus on early detection of animal health issues.

LOW PRIORITY

a. **Pasture quality -** A relatively small investment is recommended to establish proof-of-concept in NIRS/Hyperspectral spectroscopy to estimate pasture quality parameters and to determine the potential accuracy of the information relevant for improved feed allocation, animal management and plant nutrient status.

b. **Weed Management –** A small proof-of-concept study is recommended to examine the potential of NIRS/Hyperspectral spectroscopy to detect green weeds in green pasture swards, and to determine its capacity to quantify percentage weed infestation.

c. **Pasture yield mapping –** Because of the need for estimates of actual pasture productivity at the sub-paddock scale, taking into account animal intake, any investment should be delayed until other investments are concluded and the capacity to estimate pasture biomass and animal intake is known.

d. **Feed prediction –** A more thorough review is recommended to understand the forecast/prediction requirements for key decision points in production systems, the capacity of current forecasts, and build a strategy for ongoing R&D and delivery. A watching brief is required on advances in the climate forecast models as these are continually improving and will underpin an ability to forward-prediction feed availability and quality.

Glossary

ABBREVIATION	DEFINITION
3G	3rd Generation Mobile network technology
4G	4th Generation Mobile network technology
Apps	Application: a computer software applications that include web browsers and custom applications for smart phones, tablets and other consumer devices.
Big Data	Big data is a collection of data sets so large and complex that it becomes difficult to process traditional database tools or data processing applications.
CCI	Comprehensive Climate Index: A comprehensive index for assessing environmental stress in animals
Cloud	The practice of using a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local server
DSS	Decision Support System: A set of related computer programs and the data required to assist with analysis and decision-making within an organization.
GDP	Gross domestic product (GDP) is the market value of all officially recognized final goods and services produced within a country in a given period of time.
GSN	General Sensor Network : A middleware for efficient and fexible deployment and interconnection of sensor networks
Internet of Things	The Internet of Things (IoT) is a computing concept that describes a future where everyday physical objects will be connected to the Internet and will be able to identify themselves to other devices.
GPS	Global Positioning System: A satellite based technology to determine position
HLI	Heat Load Index: An index combining temperature and humidity used to assess heat stress in cattle.
IP	Internet Protocol: Defines the basic structure of packets of information on a data network
kbit/s	kilobits per second : 1000 or 1024 Bits Per second
LAN	Local Area Network: An IP network constrained to a small area, such as a home
LTE/4G	Long Term Evolution: The emerging generation of mobile networking technology
Mbit/s	Megabits per second
Middleware	Middleware is computer software that provides services to software applications beyond those available from the operating system.
NBN	National Broadband Network: Australia's version of a next generation network
NGN Broadband	Next Generation Network Broadband: Broadband networks that provide for bandwidth scalable to levels at least 25 Mbps, is generally symmetric (with upload speed close to download bandwidth), provides for quality of service, is universal in coverage, and has the ability to interconnect to other networks such as local sensor networks.
Semantic Web	The Semantic Web provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries.
Sensors	A device that detects or measures a physical property and records, indicates, or otherwise responds to it.
TFP	Total Factor Productivity: compares total outputs relative to the total inputs used in production of the output(s).
RFID	Radio Frequency Identification: A simple technology using very low power radio frequency waves to transmit small amounts of data over short distances
RSP	Retail Service Provider: NBN definition of a provider of internet services to end consumers
W3C	World Wide Web Consortium: An international industry consortium founded in 1994 by Tim Berners-Lee to develop standards for the Web
WAN	Wide Area Network: An IP network that spans beyond the local area, such as outside the home

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UNE

The University of New England was the first Australian university established outside a capital city. UNE has a well-earned reputation as one of Australia's great teaching, training and research universities. The Precision Agriculture Research Group (PARG) is a multi-disciplinary team of academic, research and technical staff engaged in the development and application of sensors and practices in precision agriculture.

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