Accelerating Precision Agriculture to Decision Agriculture: Enabling Digital Agriculture in Australia

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Abstract. *For more than two decades, the success of Australia's agricultural and rural sectors has been supported by the work of the Rural Research and Development Corporations (RDCs). The RDCs are funded by industry and government. For the first time, all fifteen of Australia's RDC's have joined forces with the Australian government to design a solution for the use of big data in Australian agriculture. This is the first known example of a nationwide approach for the digital transformation of an agriculture sector, internationally.*

The Accelerating precision agriculture to decision agriculture project collaborated with six leading research organisations evaluated the current and desired state of digital agriculture in Australia and made recommendations for Australian primary producers to overcome the challenges currently limiting digital agriculture and profit from their data. The project conducted surveys of producers to understand their needs, drivers and level of knowledge; reviewed the state of and requirements for data connectivity on and off-farm; explored legal aspects looked at rules concerning data ownership, access, privacy and trust; assessed data sets currently available and what will be needed for digital agriculture in Australia; and it developed a big data reference architecture to support interoperability across datasets and systems into the future.

Digital agriculture in Australia was found to be in an immature state in many parts including strategy, culture, governance, technology, data, analytics, and training. This is to the detriment of innovation and producer adoption of digital agriculture in Australia. With maturity, the economic modelling identified that the implementation of digital agriculture across all Australian production sectors (as represented by the 15 RDCs) could lift the gross value of agricultural (including forestry, and fisheries and aquaculture) production by $20.3 billion (a 25% increase on 2014). Thirteen recommendations are made in the areas of policy, strategy, leadership, digital literacy and enablers. To achieve maturity, cross industry and cross-sector collaboration is vital as many of the issues impeding maturity are common and this scale of investment is required to implement solutions for Australian conditions and to keep pace with the rest of the world.

Keywords. *Agriculture, data, digital agriculture, Australia*

Potential economic benefit of digital agriculture in Australia

Benefits of digital agriculture to the Australian economy were predicted using the Centre for International Economics (CIE)- Regions Food Processing model (CIE-Regions FP model), a general equilibrium model of the Australian economy with a focus on agriculture and food processing (Perrett et al., 2017). The potential of unconstrained digital agriculture was determined by estimating the increase in productive potential delivered by digital technologies.

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

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

The model conceptualised that the full implementation of digital agriculture would deliver producers, in a timely fashion, all the data, information and analysis that they need such that all the constraints on productivity that are within the control of the producer are eliminated. In this case, the productive potential would only be limited by the genetic potential and environmental limitations for which the producer has no control. The economic benefit from productivity improvements that can be assumed to result from fully adopted digital agriculture therefore becomes the difference between the genetically and environmentally limited yield, and current production practice - in which productivity may be constrained by management decisions as well as genetic and environmental potential (Perrett et al., 2017).

The productive potential information used for this project was obtained through a series of interviews with experts identified by each participating RDC. The shocks that were applied to the CIE-Regions FP model were determined by grouping suites of similar technologies into production factors or key decision areas. For example, for the grains sector, better nutrient application was identified as a single shock since the contribution that better nutrient application has to the overall yield gap could be estimated and better nutrient application encompasses a suite of digital applications. Likewise, for the beef industry, animal health and monitoring has been identified as a shock since the contribution that increased animal health makes to productivity improvement can be reasonably estimated, and there is a distinct grouping of digital technologies that provide information for this factor (Perrett., 2017). If there was not clear information available about unrealised genetic potential then benchmarking studies were examined, so that estimations of possible improvement did not go beyond what is known to be possible and being achieved by the very top producers (Perrett et al., 2017).

When digital agriculture is fully implemented in Australia, it is estimated that this would boost the value of agricultural production, including forestry, fisheries and aquaculture, by 25% (compared to 2014-15). This is a $20.3 billion boost to the gross value of agricultural production (GVP) (Table 1). The overall potential increase in national gross domestic product (GDP), including the flow-on effect to other parts of the Australian economy, is estimated to be $24.6 billion. As discussed previously, these estimates are considered to be a conservative best-case situation. They assume a 100% uptake of digital agriculture and exclude any costs associated with the adoption of digital technologies. The productivity gap between fully-enabled digital agriculture and the current state reflects the size of the opportunity that has yet to be fully captured (Perrett et al., 2017).

Table 1: The potential unconstrained economic benefit of digital agriculture in Australia

Sector	Baseline sector value (GVP) 2014-2015 ($m)	Potential benefit to the sector		Potential benefit to the economy
		GVP[1] Increase ($m)	GVP Increase (%)	GDP[2] Increase ($m)
Rice	260	78	30	46
Grains[3]	9,149	4,703	51	1,446
Cotton	1,413	394	28	692
Sugar	1,257	291	23	660
Horticulture[4]	1,018	403	40	951
Beef	10,461	1688	16	4,219
Sheepmeat	2,988	516	17	1,316
Wool	2,550	452	18	1,128
Pork	1,084	55	5	429
Dairy	3,343	497	15	1,298
Eggs	729	180	25	128
Chicken Meat	2,084	503	24	371
Wine	5,865	706	12	630
Forest and Wood Products	14,864	5,511	37	7,484
Livestock Exports	1,601	72	4	179
Red Meat Processing	14,533	2081	14	2,438
Fisheries and Aquaculture	2,132	928	44	855
Total	**75,331**	**19,058**	**25**	**24,270**

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

Cross-industry use cases

Increased process automation and labour savings

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

The opportunity estimated by the economic modelling that may be achieved through process automation and labour savings across sectors is a GVP increase of $7.4 billion (Perrett et al., 2017). The cotton, horticultural and forestry industries illustrate opportunities for substantial percentage increases in productivity due to automation.

Tailoring inputs to need

Varying inputs, such as nutrients and seed, to better match the unit needs of individual animals, plants or groups of animals and areas of land, offer production and environmental benefits. The application of variable rate technology (VRT) to increase productivity has relevance across most agricultural sectors. VRT is currently at different stages of advancement in different agricultural sectors (Leonard et al., 2017).

Economic modelling has estimated that across sectors, better targeting of crop and pasture nutrition as well as feed and water in extensive livestock would improve GVP by $2.3 billion (Perrett et al., 2017). Nearly a third of this improvement is anticipated from the beef sector. The sugar industry is estimated to achieve the greatest productivity improvement from the better targeting inputs.

Accelerating genetic gains through objective data

Major improvements in plant and animal genetics have been achieved using genetic benchmarking and genomics tools. Data analytics has the potential to accelerate these methods by integrating this information with performance data from other sources such as insights that link genetic, production and processing data (Leonard et al, 2017).

By achieving better breeding, genetic selection and rotation decisions through the application of digital agriculture, economic modelling estimated an improvement in GVP of $2.9 billion. More than half of this was attributed to improving crop rotations in grain production (Perrett et al., 2017)

Improving market access and biosecurity

Traceability, provenance and biosecurity are key areas that producers and industry are looking to digital agriculture for answers. An immediate economic benefit will be realised from improved management resulting from the data collected as part of broader biosecurity efforts. For example, the monitoring of animal health for disease outbreaks is just as useful for measuring the performance and profitability gain. Likewise, disease monitoring for biosecurity incursions in horticulture will provide management information required for more efficient production and efficiency of animals for productivity (Leonard et al., 2017)

Economic modelling estimated an increase in GVP of $1.0 billion could be achieved through management platforms that form part of broader traceability and biosecurity efforts (Perrett et al., 2017). Animal health and disease monitoring in the beef industry was estimated to gain significantly from this approach.

The current state of digital agriculture in Australia

An assessment of the current state of digital maturity of the agricultural sector, with a particular focus on its use of data to drive decisions was undertaken. This assessment is an important starting point for the findings and recommendations in this report. It also provides a guide to the agricultural industries for the transition to digital agriculture. The current digital maturity of the agricultural sector in Australia has been rated as 'ad hoc', meaning it does not systematically and consistently use data to drive decisions. The impact of this is that the sector is missing out on opportunities to improve productivity and realise greater profits (Skinner et al., 2017).

The assessment is made against seven key pillars of success for digital maturity, namely strategy, culture, governance, technology, data, analytics and training is summarized below:

Leadership: A need for greater leadership in digital agriculture was identified, with common issues across industries. There is a need for digital agriculture policy, governance, strategy and cross industry collaboration.

Trust & Legal Barriers: Currently, the legal and regulatory frameworks around agriculture data are piecemeal and ad hoc. 56% of producers indicated having no trust or little trust in service/technology providers maintaining their data privacy (Zhang et al., 2017).

Connectivity: A lack of access to mobile and internet telecommunications infrastructure is a major impediment to the adoption of digital agriculture systems. 55% of producers reported that they relied on the mobile phone network for internet, yet 43% had patchy or no mobile reception across their property (Zhang et al., 2017).

Digital Literacy: A digital skills and capability gap was identified across the value chain, including within the RDCs. It was identified that education support was not only required to up-skill the agricultural sectors but also to generate more data scientists and engage them with agriculture.

Value Proposition: Producers indicated the value of changing to digital agriculture is not clear. Value was not only related to monetary value, but also peace of mind, confidence, social and lifestyle factors. If digital agriculture is to be adopted, it needs to be sustained by consistency of service and support and the reliability of technology.

Availability of Appropriate Data: The whole agriculture value chain irrespective of industry sector could gain from improved access and interoperability of stored data through dissemination of datasets that are valuable across the rural sector that are also widely used in other industries.

Data Analysis and Decision Support Tools: There is a need for a platform for owners and users of agricultural data to exchange, market and value add data for a variety of end purposes. Fully-enabled digital agriculture require models and analytics with the ability to transform data into insights applicable to decision-making (Leonard et al., 2017).

Key recommendations to achieve the future state of digital agriculture in Australia

Thirteen recommendations are made to fully enable digital agriculture in Australian to lift in the gross value agricultural production (GVP) of $20.3 billion. For this potential to be realised, it will be essential for industry, RDCs, government and the commercial sector to commit to work together in each of the following areas: Policy, Strategy, Leadership, Digital Literacy, Enablers.

A. Policy

RECOMMENDATION A1: A Data Management Policy for Australian Digital Agriculture is established to provide governance for the control and use of data to improve the inter-operability of datasets and help build trust.

One of the first steps for industry in implementing good data management procedures is to establish a national data management policy. This is a set of broad, high level principles that will form the guiding framework in which data access and management can operate. More specifically, a data management policy for Australian digital agriculture must consider issues such as data custodianship and access, data collection and storage, data harmonisation and standardisation, data stewardship, data security, data portability, data lifecycle management and data audits (Leonard et al., 2017 and Wiseman et al., 2017).

RECOMMENDATION A2: A voluntary Data Management Code of Practice and a Data Management Certification or Accreditation Scheme are investigated in line with the Data Management Policy for Australian Digital Agriculture to provide quality assurance of Australian agricultural data.

Australian producers want to know that their data is adequately protected and used fairly. Currently, many Australian producers do not trust service/technology providers with their data. A lack of trust in the way data is managed was identified during the survey phase of the project, with 56% of respondents having no trust or little trust in service/technology providers not sharing their data with third parties (Zhang et al., 2017 and Wiseman et al., 2017).

Implementing a data management code of practice and certification or accreditation provides mechanisms to increase transparency and trust. One way this will be achieved is by developing trust and greater transparency about the terms of use that govern the collection, aggregation, ownership, storage and dissemination of data. This trust and transparency are essential prior to producers entering into commercial relationships with third-party advisers and technology service providers (Leonard et al., 2017)

B. Strategy

RECOMMENDATION B5: Each of the 15 Research and Development Corporations (RDCs) develop a Digital Agriculture Strategy in line with Data Management Policy for Australian Digital Agriculture.

There is an absence of clear digital strategies within the RDCs, as evident from interviews and observations gathered during the P2D project. This indicates that the RDCs lack a clear roadmap for the adoption of digital agriculture.

Example reference architectures (see recommendation B6) and the Architecture Decision Support Tool have been developed in this project to support RDCs in the development of digital strategies and implementation plans (Leonard et al., 2017 and Skinner et al., 2017).

RECOMMENDATION B6: To instigate a Big Data Reference Architecture for Digital Agriculture and Data Management Implementation Plan that is consistent with the Data Management Policy for Australian Digital Agriculture.

The reference architecture can facilitate collaboration between RDCs by creating a language and approach when addressing digital agricultural and big data challenges (Leonard et al., 2017 and Skinner et al., 2017).

RECOMMENDATION B7: That Foundational Datasets including soils, climate and market data are reviewed, established and enhanced for use cross-industry.

There are several core or foundational datasets, which form the basis of public and private sector digital agricultural systems including land boundaries, climate, weather, soils, market and biosecurity preparedness and surveillance. Some of these lack quality and density of information or are on different scales. Farm boundary data is also considered a core dataset needed by industry. While existing for legal (rateable) boundaries by local government, this does not currently exist as a publicly available, up-to-date dataset for cadastral (physical farm) boundaries (Barry et al., 2017 and Leonard et al., 2017).

There is a clear need to move from simple data portals that aggregate raw information to information systems that produce data that can be used directly in analysis. Investment is needed to fully leverage the existing data holdings. Datasets that are missing, incomplete or held in formats not readily accessed for commercial deployment represent a significant barrier to use. There is a clear need to provide quality assured data that is maintained over time to remain fit for purpose.

The integration of privately collected data into the soil and weather/climate datasets that form an essential foundation for digital agricultural systems should be investigated, such as the establishment of an Australian Soil Information Facility. Inter-operability of datasets is essential to turn data into decisions (Barry et al., 2017 and Leonard et al., 2017).

Producer and industry representatives have identified quality and access issues with existing foundational datasets, which support a large number of cross-industry management decisions. The use of data in Australian digital agriculture could be transformed through cross-industry adoption of best data practice, based on the approach described in the Big Data Reference Architecture.

RDCs have a fundamental role in the generation of knowledge to underpin digital agricultural applications, but should not lead the development of software programs or digital agriculture platforms to be used by farm service organisations or producers. It is the role of the private sector to develop digital agriculture software programs and platforms, however the RDCs should explore new partnership and funding models to support innovation in digital agriculture (Barry et al., 2017 and Leonard et al., 2017).

C. Leadership

RECOMMENDATION C8: The Australian Government, in collaboration with the 15 Research and Development Corporations (RDCs), makes a long-term commitment to digital agriculture by establishing and investing in a Digital Agriculture Taskforce for Australia (DATA) headed by the Chief Digital Agricultural Officer (separate from the Australian Government Chief Digital Officer).

Interviews with the RDCs identified a lack of technical leadership within industry organisations from a national to a community level.

Staffed by a small cross-industry team of data scientists, technologists and legal experts, DATA would have the broad objectives of:

- Identifying and initiating collaborative data opportunities.
- Building foundational datasets.
- Developing and supporting implementation of a cross-industry digital agricultural strategy.
- Refining and growing the Big Data Reference Architecture (see recommendation B7).
- Monitoring and guiding telecommunications and connectivity; and
- Developing data science capability.

Instigating the recommendations B6-B7, D10 and E11-13 is considered the responsibility of Digital Agriculture Taskforce for Australia (DATA) (Leonard et al., 2017).

RECOMMENDATION C9: A Digital Agriculture Taskforce for Australia Working Group (DATAWG) is established to drive the policy and investment required to advance digital agriculture in Australia. The group would consist of representatives from the 15 Research and Development Corporations (RDCs), Government and peak industry and commercial representative bodies and relevant industry experts.

Instigating the recommendations A1-A4 and C8 is considered the responsibility of Digital Agriculture Taskforce for Australia Working Group (DATAWG).

At the heart of digital agriculture are telecommunications connectivity and data analysis leading to better informed decision making and implementation. The technologies, enabling functions and many datasets that support digital agriculture are not sector specific. This commonality of issues reinforces the need for cross-sectoral collaboration to produce uniform policy in areas that will facilitate the unconstrained implementation of digital agriculture (Lamb, 2017 and Leonard et al., 2017).

D. Digital Literacy

RECOMMENDATION D10: That the 15 Research and Development Corporations (RDCs) and the university sector strategically invest in education and capacity building for students, producers, agribusinesses, rural industries and their stakeholders to increase digital literacy and application in the agricultural sector.

There is a need, both in the research and development (R&D) sector and in industry, for people with digital skills who also understand the agricultural sector. Evidence from the regional stakeholder workshops indicates that the Australian university system is not producing sufficient agronomists with the required skills and that current incentives to change this situation are insufficient.

Education and training are required at all levels within the industry to increase knowledge and understanding of connectivity options, best practice in data management and use and data licensing. New programs should also be developed to provide the relevant skills to the emerging agricultural workforce that will be required to progress digital agriculture.

A review of the skills required by producers to maximise the benefits derived from digital agriculture is recommended to provide a foundation for the development of educational packages. The establishment of demonstrator sites could be considered to enable producers gain first-hand experience of innovations and best practice in data management in a practical environment.

Skill gaps have already been identified in the areas of on-farm telecommunications and data science, but a more comprehensive analysis is required (Leonard et al., 2017).

E. Enablers

RECOMMENDATION E11: That DATA collaborates with peak industry bodies and the Carriage Service Providers (CSP) to establish baseline patterns of data usage and an on-going national mobile network coverage (data speed and volume) database.

There is no quantitative data available on the diurnal and seasonal demands for data use farming businesses or on data speed requirements for different farming business operations. However, it is known that on-farm demand is growing as was illustrated by the higher than expected demand for NBN in rural and regional Australia.

Quantifying on-farm coverage will help support strategic planning of future national connectivity initiatives (Lamb et al., 2017 and Leonard et al., 2017).

RECOMMENDATION E12: Options to digitise and automate data collection including for regulatory compliance activities are reviewed.

Currently, there is a burden on producers to collect and submit much of their data for analysis, including regulatory compliance data and information for ABARES surveys. The lack of data culture within agriculture, plus the high level of effort in creating this data, means that it is often produced at a low or inconsistent quality, data may not be calibrated or, often, the data is just not collected at all.

Some implications of digital agriculture will occur beyond the farm gate and will lead to potentially substantial indirect benefits. Issues such as biosecurity monitoring and regulatory compliance for food safety are critical whole of agriculture issues that will require an industry (and government) response to the collection and sharing of data (Leonard et al., 2017).

RECOMMENDATION E13: A Cross-Industry Survey is executed every three years to identify producers' needs and issues in digital agriculture technologies and the application of big data.

In consultation with P2D project members and participating RDCs, CSIRO designed the survey questionnaire and conducted a survey of 1,000 producers across 17 agricultural industries. The study investigated producers' needs, perceived risks and benefits, and expectations from three aspects - telecommunication infrastructure, the status of current data collection, and data sharing and concerns in the big data context (Leonard et al., 2017 and Zhang et al., 2017).

The results from this study provide a baseline of needs and issues relating to on-farm adoption of digital agriculture. Resurveying every three years will not only identify new needs and issues, but highlight how past needs and issues have been addressed.

More targeted studies focusing on particular aspects for specific industries on a more regular basis will help to inform strategies at the industry level.

Summary

For Australian agriculture to realise the potential $20.3 billion benefit from digital agriculture, thirteen recommendations have been made in key areas of policy, strategy, leadership, digital literacy and enablers that must be addressed for the elements of trust, confidence, functional delivery and operational effectiveness to achieve data driven practice change by producers.

For this potential to be realised, it is essential for industry, RDCs, government and the commercial sector to work together. The P2D project has the benefit of being supported by all of the RDCs and the Australian Government, enabling a co-ordinated national approach.
A series of reports and web based tools have been developed as an outcome of this research and can be found here - https://www.crdc.com.au/precision-to-decision. The following web based tools were developed -

- A Big Data Reference Architecture for Digital Agriculture: developed by the Data to Decisions CRC, this tool incorporates example decision trees defining the data needs for an agricultural data system with full consideration of data systems existing in the broader economy.
- Register of cross-sectoral agricultural and environmental datasets and decision support tools: developed by CSIRO DATA 61.
- An online grower toolbox: developed by Griffith University and USC, providing best practice guidance material for growers and industry.

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