Charles Sturt University

Potential implications and benefits for the agricultural technology sector from the introduction of the Australian Agricultural Data Exchange

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Glossary of Terms

Term	Meaning
AADX	Australian Agricultural Data Exchange
AAFDX	Australian AgriFood Data Exchange
ABS	Australian Bureau of Statistics
AEF	Agricultural Industry Electronics Foundations
AgTech	Agriculture Technology vendors
AI	Artificial Intelligence
API	Application Programming Interface
APPs	Australian Privacy Principles
CCPA	California Consumer Privacy Act
CSIRO	Commonwealth Scientific Industrial and Research Organisation
DA	Data Act
DGA	Data Governance Act
DQR, SRR, SSR, IR	Refers to Data Quality Risk (DQR), System Reliability Risk (SRR), System Security Risk (SSR), Interoperability Risk (IR)
DX	Data Exchange Platform
ESG	Environmental, Social and Governance
FACRC	Food Agility CRC
GDPR	General Data Protection Regulation
ML	Machine Learning
NFF	National Farmers Federation
OT	Operational Technology
PII	Personally Identifiable Information
PIMS	Privacy Information Management System
PUC	Passive Uplink Connection
SCADA	Supervisory Control and Data Acquisition
SME	Small and Medium Enterprises

Executive Summary

Although the role of an AADX in the future of the Australian agricultural sector is yet to be defined, that a culture of data sharing will drive innovations across the sector.

The Australian Agricultural Data Exchange[1] (AADX) is an initiative, launched in August 2020, with the vision of enabling agricultural industry participants to leverage a common data sharing infrastructure for the benefit of the agricultural sector. The data sharing gaps identified within the sector were believed to have led to inefficiencies and missed opportunities for the sector. Thus, by addressing these gaps through a data exchange (DX) infrastructure, benefits ranging from enhanced management capacity to predictive biosecurity were envisaged.

In September 2022, a Charles Sturt University research team was engaged to investigate the potential implications and benefits for the agrifood technology sector through the introduction of the AADX. The team adopted a mix of qualitative and quantitative approaches for the research study. For the qualitative part, a total of 15 Australian agricultural technology (AgTech) vendors and seven public agricultural data exchanges across the world were interviewed. For the quantitative part, 32 Australian agricultural technology vendors were surveyed, representing a 15% survey response rate. The qualitative data was analysed and triangulated with the survey data and secondary research to derive insights into the implications, merits and challenges that may arise from the existence of an agricultural data exchange in Australia. Five broad thematic narratives emerged around the study viz: (1) the agricultural data sharing landscape; (2) the data exchange opportunity; (3) data exchange barriers and risks; (4) characterising the adoption of data exchanges; and (5) the impact of data exchanges.

In the agricultural data sharing landscape, it was observed that agriculture has a relatively complex supply chain, and the key focus group in this study—AgTechs—only forms a portion of that chain, albeit with a significant impact. Although measuring the value of data in the context of data sharing is difficult, AgTechs appreciate the importance of data and data sharing within their businesses, and indeed adopt different ways to achieve this. In fact, 72% of survey respondents indicated their ability to adapt to an Australian DX, while 57% indicated a strong interest in adopting an Australian DX as soon as it becomes available.

In the data exchange opportunity, data management practices are clearly considered important amongst AgTechs, with 88% having introduced new data management practices in the last five years. Further, data sharing is an active part of their businesses. Indeed, 94% of survey respondents share data with one or more external parties, while 50% share data with at least 21 external parties.

However, 41% and 25% are not satisfied with their inbound and outbound data integrations respectively. This represents a clear opportunity for a DX to facilitate effective data sharing and integration amongst AgTechs. This is likely to lead to several priority services benefits including the availability of quality data that is findable, accessible, interoperable and reusable for generating data insights—noting that 97% of AgTechs reported using data to generate insights.

1 Formerly, Australian AgriFood Data Exchange (AAFDX)

In exploring the data exchange barriers and risks, while 72% of AgTechs are generally in support of an AADX, much of this support comes from smaller AgTechs with fewer than 20 employees and less than 10 years in business operation. This points to a barrier that may stem from a reluctance of AgTechs—who may have accumulated data over the years—to share it freely on a DX without any perceived commensurate benefits. Lack of trust, and the perception that the AADX is a top-down imposition were also clearly identified as barriers among AgTechs in this study. The barriers identified are also interrelated with the risk of a data monopolisation by the AADX, which could create a considerable data power imbalance. This is to be mitigated by stringent and transparent governance structures. Other risks identified are technical in nature and relate to data quality, system reliability, system security, interoperability and user interface. If not mitigated these risks can affect the trust, confidence and usefulness of the AADX. Data governance such as regulations, standards and policies are imperative to mitigate these risks.

In characterising the adoption of the AADX, two key factors are seen as drivers for maximising stakeholder benefits and participation opportunities. Firstly, facilitating the democratisation of data by the AADX will ensure greater opportunities for a wider range of stakeholders to participate in the DX. Secondly, early engagement with industry bodies, who often serve as trusted intermediaries to the industries they represent, will assist in understanding and mediating any conflicting interests that may arise. This will mitigate alienation and encourage broader participation within the sector. Further to this, factors such as price, governance, terms and conditions for participation, types of available data, data quality standards, and security standards were ranked as the top six factors that will affect optimal participation in an AADX.

Finally, in exploring the impact of a data exchange, it is critical that use cases that are prioritised exemplify the impact of AADX across the length of the supply chain. This will be key, not only in attracting the most DX participants, but will also drive a flow on effect in accelerating the adoption of agriculture technologies more generally. Further, the top five sources of data that should be included in the AADX to have the most impact, ranked by AgTechs, were data from producers and processers; data from other AgTechs; open data; government data; and domestic and global markets data.

Although the role of an AADX in the future of the Australian agricultural sector is yet to be defined, it seems obvious that a culture of data sharing will drive innovations across the sector. The role of the AADX in facilitating data sharing is likely to be embraced if the key adoption barriers and risks are mitigated.

1 Introduction

The aim of this research is to identify the opportunities and challenges that a DX presents to AgTech vendors, and to describe the conditions for optimal participation in an Australian DX by the AgTech sector.

In August 2020 an initiative called the Australian AgriFood Data Exchange (AAFDX) was launched outlining a proposal for an Australian agricultural data exchange to be overseen by the agrifood industry. The purpose of the proposed DX was to enable sharing, reuse and merging of data from disparate systems by participants in a secure environment on a permissioned basis. The AAFDX—now called the Australian Agricultural Data Exchange (AADX) to better reflect the whole agricultural industry—was envisioned to allow industry participants to leverage a common data sharing infrastructure to generate insights and stimulate sustainable entrepreneurship and consumer assurance.

The core gaps identified within the Australian agricultural industry by the AADX initiative were threefold. Firstly, the absence of a single, easy-to-use platform in Australia to allow primary producers and other stakeholders to exchange their data efficiently on agreed terms with trusted service providers. Secondly, the inability of agricultural supply chain stakeholders to take full advantage of the vast amounts of data generated. Thirdly, the predominance of disparate, siloed and proprietary data systems that do not enable data owners to easily access and directly exchange their data. These gaps were perceived to have led to inefficiencies, poor collaboration, wasteful use of critical managerial time and loss of opportunities for the sector.

In addressing these issues, it is anticipated that an Australian data exchange in the form of the AADX initiative would generate the following benefits:

1. Enhanced management capacity;
2. Consistent and centralised traceability within data systems;
3. Verification assurance to consumers and regulators to support market access;
4. Improved access to natural capital and risk-adjusted financing and insurance opportunities;
5. Digitised compliance;
6. Data sharing; and
7. Improved predictive biosecurity capabilities.

In September 2022, a research team from Charles Sturt University was engaged to investigate the potential implications and benefits for the agrifood technology sector from the introduction of the AADX. The research framework adopted, and the organisation of the resulting findings are set out below.

1.1 Research Framework

The research framework outlines the research aim and objectives, and the research methodology adopted to achieve these.

1.1.1 Research aim and objectives

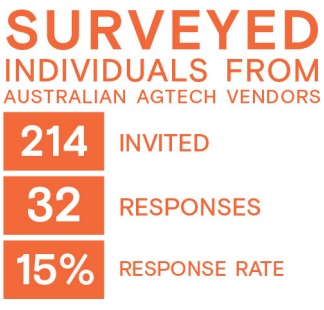
The aim of this research is to identify the opportunities and challenges that a DX presents to agricultural technology (AgTech) vendors, and to describe the conditions for optimal participation in a DX by the AgTech sector within the Australian context.

In line with this aim, this research project had the following research objectives (RO):

- **RO1** — Investigate the priority service benefits for the AgTech vendor community and the customer service requirements that the AADX might need to provide to this user group;
- **RO2** —Explore the potential barriers to engagement with the AgTech sector and to recommend ways of overcoming these;
- **RO3** —Stratify any identified risks to AgTech vendors that might arise from the existence of the AADX, and recommend relevant standards to mitigate risks for the AADX;
- **RO4** —Consider how the AADX may be designed to maximise benefits and participation opportunities for small, medium and large AgTech vendors;
- **RO5** —Identify the opportunities that the AADX presents to AgTech vendors;
- **RO6** —Explore the factors that affect optimal participation in the AADX by the AgTech sector;
- **RO7** —Explore the impact of the AADX on the adoption rates of AgTech by other stakeholders in the agricultural sector; and
- **RO8** —Develop a list of public datasets that could be included in the Australian agricultural DX data catalogue.

1.1.2 Research methodology

To gain both a broad and nuanced understanding of the subject matter, a mix of qualitative and quantitative approaches was adopted in this study. Overall, the research team undertook semi-structured interviews with individuals from 15 Australian AgTech vendors and seven global public data exchanges working with AgTech vendors across the world. In addition, the team invited individuals from 214 Australian AgTech vendors to complete a survey. As of 31 May 2023, 32 complete responses were obtained, amounting to a response rate of 15%.



The qualitative data was thematically analysed and triangulated with the survey data and secondary research into the technological and governance standards, as well as factors affecting the participation in a DX. This information was coupled with an exploration of the grey literature on the topic, including research by international organisations like the World Economic Forum, and from commercial and non-profit technology companies. Publicly available examples of existing use cases, go to market strategies and datasets were also explored to inform the research objectives.

Below, we describe the research design considerations, and detail each of the qualitative and quantitative approaches.

Research design considerations

Over the course of the research, it became apparent that certain considerations needed to be made in the research design. These are outlined as follows:

Sensitivity of subject	This project was considered sensitive due to the multiple, competing interests that surround its operationalisation, as gleaned from previous engagements of various stakeholders with the concept of an AADX. Anonymity and deidentification of interview data were important to protect privacy of participants and to ensure a comfortable environment for interview participants to voice themselves.
Classification of interview participants	A data exchange is not concretely defined in the literature. The operational characteristics of an Australian agricultural DX are also yet to be defined. Based on publicly available information and secondary research, interview participants were classed either as AgTechs or a DX for the interview purposes. Where participants expressed being both an AgTech and a DX, this was duly acknowledged. This consideration is important because it informs the definition of a conceptual framework of an Australian DX. It also brings awareness to the existence of solutions, and their scope thereof, in addressing the challenge of data sharing.
Flexible research design	The research adopted flexible research methods. For example, it was anticipated that all interview and survey participants would reflect sufficiently large representative samples of the population. However, initial interactions with sections of the AgTech community pointed to participant fatigue relating to previous engagements with the AADX. As such, convenience sampling was adopted. We realise the potential of convenience sampling to affect the representativeness of the data, however best efforts have been taken to ensure diversity in the demography of the participants in this research.
Ethical considerations	This project has Human Research Ethics Application approval from Charles Sturt University's Human Research Ethics Committee (Protocol Number: H22424).

Qualitative approach

This research employed semi-structured interviews to enable participants to freely articulate their views within a predetermined scope of the issues, permitting a comparative approach to data analysis. Due to time constraints and recruitment limitations, convenience sampling was used for data collection. Interview participants were recruited via email and phone calls based on available contact information. Those contacted were chosen for their experience within the AgTech and DX industry and not as representatives of their organisations. Interviews were focussed on the interviewees' understanding of the particular AgTech or DX they either owned or were employed by. The views expressed were their own and not necessarily that of their organisation.

A total of 22 semi-structured interviews were conducted with individuals from two groups of businesses: (1) public agricultural data exchanges (n=7) and (2) Australian AgTech Vendors (n=15). DXs were sampled from an initial market scan previously undertaken as part of the broader AADX initiative. Interviews occurred between 30 January 2023 and 27 April 2023, and were recorded and transcribed for further analysis. Australian AgTechs were identified from the online AgTech directories, AgTech finder[2] and Ausagritec[3]. Those shortlisted for the study were chosen to cover a range of sizes, technologies and age to ensure as much variability in the study as possible within the constraints described. Participants ranged from pre-venture funding startups, employing a couple of founder members with limited developer contractor support established within the last five years, to publicly listed global information technology enterprises with extensive development and consulting teams established over a century ago. All interviews were recorded and transcribed for further analysis. For simplicity, where the term AgTech is used in the rest of this document, it refers to the participants in this study.

Quantitative approach

Based on the responses from the semi-structured interviews conducted with the DXs, a survey questionnaire was developed for Australian AgTech providers. The questionnaire comprised questions regarding:

- Demographic characteristics (e.g., business size, number of employees)
- Current and projected future use of data and management
- Current and projected engagement with data exchanges
- Views on the idea of an AADX
- Open-ended questions.

The questionnaire is provided in the Appendix A3.

Between 28 March 2023 and 2 May 2023, a total of 214 participants from various Australian AgTechs were contacted via email by the research team. A follow-up reminder email was sent one week later. The survey was conducted via the online platform, Qualtrics. As of 31 May 2023, a total of 32 complete responses were obtained, representing a response rate of 15%. Although another 28 responses were received, these were not analysed due to incompleteness. The survey data are summarised and presented using various graphical and summary statistics. The results were analysed in relation to the interview data.

2 https://agtechfinder.com/company-directory
3 https://ausagritech.org/membership/agritech-members-directory/

1.1.3 Research scope and limitations

This study focussed on the benefits, opportunities, and challenges in establishing an AADX from the perspective of AgTech vendors in Australia. As such, the scope of this research was limited to engaging Australian AgTech vendors to understand their needs and concerns regarding working with the AADX. These were complemented by insights from semi-structured interviews with European and other DXs interviewed for this project. The following limitations are identified in this research:

Farmers

Although farmers are key players in the agricultural sector, we did not speak to them directly. Considering the value and amount of data produced by farmers, their degree of participation will likely affect the success or failure of a DX. Furthermore, farmers are the main customers of AgTech providers and therefore the potential impacts of the AADX on their businesses should be carefully considered. Consultations to gauge farmers' needs and perspectives are recommended prior to the implementation of the AADX.

Supply chain

This project focussed on the sections of the agricultural supply chain involving AgTechs. There was no engagement with high value parts of the supply chain, e.g., financial services with their Environmental, Social and Governance (ESG) requirements; supermarkets and food manufacturers with their provenance requirements; commodities traders; or fertiliser companies who need to forecast demand for product. A multistakeholder approach to consultation is recommended to ensure value is derived from all parts of the supply chain, including those of high value.

Data

Convenience sampling does not purport to be representative. Although the interviewees and survey respondents cover a wide range of AgTechs with different sizes, ages, fields, and data using/sharing practices, the findings in this work may not be generalisable. Nonetheless, the data from qualitative and quantitative methods was triangulated to develop a comprehensive view of the data that could be drawn upon to engage in further studies, should a representative sample be deemed necessary in the future.

Technical risks

Due to the AADX being only at the conceptualisation stage, reasonable assumptions about the architecture of the data exchange platform have been made to facilitate the generation of this report. For example, we have assumed the data exchange platform will interact with other external heterogenous systems. Risk analyses are indicative only as they have been conducted based on the available information at the time of the report, and as such may not represent the true risk of the actual data exchange platform.

1.2 Organisation of the Report and Key Findings

The rest of this report is organised as follows:

Section 2	The agricultural data sharing landscape is explored, emphasising the agricultural supply chain, data as a commodity and the concept of data sharing within agriculture.
Section 3	The data exchange opportunities are explored by considering aspects of data sharing and management, data quality and data-driven innovations. The section further analyses the findings with respect to two key questions namely, what are the opportunities and challenges? And what are the priority service benefits? These questions relate to research objectives RO5 and RO1 respectively.
Section 4	The data exchange engagement barriers and risks are analysed. The key factors discussed relate to managing relationships and interests, data governance, risk factors and mitigations, and data reference architectures. These factors are further analysed with respect to the questions, what are the potential barriers to engagement? And what risks do DXs pose to AgTechs? These questions relate to research objectives RO2 and RO3 respectively.
Section 5	A characterisation of the adoption of data exchanges is outlined by analysing business models, value proposition, governance, stakeholder engagement, and transparency and traceability as broad aspects that impact adoption. Adoption is further analysed with respect to the questions, how do we design for maximum benefit and participation opportunities? And what are the models of optimal participation for the AgTech sector? These questions relate to the research objectives RO4 and RO6 respectively.
Section 6	The impact of data exchanges is analysed. The focus is on the data sources deemed a priority by the AgTechs. Here, relevant use case scenarios and some relevant Australian public datasets are discussed. The findings are analysed with respect to the questions, what is the impact of a DX on accelerating adoption of AgTechs? And what are the relevant public datasets that could be included in the AADX? These questions relate to research objectives RO7 and RO8 respectively.
Section 7	Presents a conclusion that summarises the key findings and discusses the future of DXs in Agriculture.

2 The Agricultural Data Sharing Landscape

Agricultural supply chains are more complex than other supply chains. They are characterised by high levels of fragmentation, in part due to the sheer number of agricultural producers.

Despite a growing acknowledgement of the utility of data to agriculture and its increasing necessity for regulatory purposes, data sharing practices within the Australian agricultural sector remain in their infancy. In the absence of a unifying coordinated system for exchanging data, peer to peer data sharing occurs informally, often using Application Programming Interfaces (APIs) and tokens. Part of the reason for the absence of a centralised agricultural DX lies in the particularity of the agricultural industry and its complex supply chains.

2.1 The Research Findings

This section of the report explores the complexity of the agricultural supply chain and its specific challenges as distinct from other supply chains. The research findings provided here yield some key concepts and context relevant to the agricultural supply chain, data value and data sharing in general. It also describes the diversity of the Australian AgTech sector and its role within the agricultural supply chain. Further, we explore the problematic issue of measuring the value of data through sharing. Finally, a data exchange conceptualisation framework is proposed to capture the diverse views on what a DX is.

2.1.1 Agricultural supply chain

Globalisation has led to an increase in supply chain length and complexity across all industries over the past 40 years. This has occurred as, for example, manufacturers seek to reduce inventory levels and focus on just-in-time production, and suppliers compete for customers who demand increasingly short lead times over an expansive range of products and services. Agriculture is not exempt from this global economic trend.

However, agricultural supply chains are more complex than other supply chains. They are characterised by high levels of fragmentation, in part due to the sheer number of agricultural producers—with estimates of over 500 million farmers worldwide (Lowder, et al., 2016)—and the wide variety of production choices available to them. This fragmentation is compounded by the risk and uncertainty associated with agriculture more generally, arising from various factors including weather patterns, yield variability and seasonal price volatility.

Further, because of their close association with human welfare (e.g., food security) and with environmental sustainability, increasingly, agricultural supply chains must conform to consumer sentiment as well as formal governance and regulatory requirements. Consumers are concerned not only with food provenance and safety (e.g., organic, halal, etc.), but also with environmental issues (e.g., carbon footprint, food miles etc.). Similarly, food security and environmental sustainability are central considerations to the United Nations 2030 Sustainable Development Goals (SDGs). While food production has its own goal (i.e., SDG 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture) many of the other goals are related to agriculture, either directly or tangentially.

A further source of pressure arises from supply chain actors (e.g., supermarkets and food processors) wanting to understand the provenance of the product they either sell or use as inputs. These implicit (from consumers, social and environmental pressure groups) and explicit mandates (from regulators and policy makers) present a requirement to understand and drive sustainability and resilience throughout agricultural supply chains; that is, to develop transparent and sustainable supply chains. A higher value-add includes the growing demand for Fair Trade products that pay a liveable wage and benefit the communities in the Global South who produce the products enjoyed in the Global North. Demonstrating that products are not linked to human rights abuses and environmental degradation—such as child/forced labour and the deforestation of rainforests in Indonesia or the Amazon—will become increasingly important in globalised agricultural supply chains. The complex economy of carbon credits and the scientific necessity of carbon capture and storage represents a further trend that cannot be ignored and that depends on high-quality data production and sharing. Demonstrating provenance requires mobilising technology to ensure traceability and transparency.

Issues of traceability also require a whole of supply chain view. Whereas the focus of attention on the impact of technologies and data on the agricultural sector is often 'on-farm'—that is, at the actual point of production—questions of sustainability, resilience, traceability and provenance must account for the entire value chain. While the agricultural supply chain encompasses a range of end products—for example textile, pharmaceuticals, fuel, construction material—its primary product is food, for both humans and animals. The food supply chain also encompasses pre and post-farmgate production, including packaging, processing, transportation, distribution and consumption. Beyond the farm a range of processes and industries occur, for example fertiliser and seed production, which cannot be left aside in the development of an AADX.

At every stage along the supply chain, value is created. This may be expressed in terms of both physical commodities and services but is most often homogenised and reflected as a series of value-adds along the supply chain. While the level of value-add is not necessarily a reflection of the importance of a particular supply chain stage but the market power of an actor (e.g., farmer versus supermarket), it is important to understand where value can be enhanced through the freeing of data flows.

Agricultural supply chains have been described as 'dendritic', that is tree-like, systems (Lezoche et al., 2020) that link numerous supply chains, and for which data may be considered the lifeblood. Such a supply chain is illustrated in Figure 1 below.

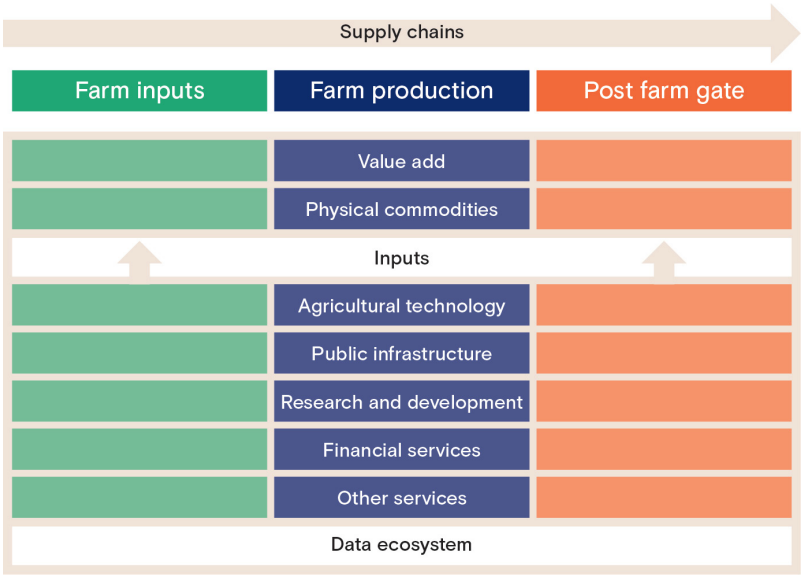


Figure 1 The Agricultural supply chain within a data ecosystem

The primary supply chain here is considered both in terms of a physical flow of commodities or its equivalent, and the value-add at each stage of the supply chain. Each of these may be considered from two perspectives. Firstly, forward from the farmgate to the consumer (post-farmgate), including activities such as packaging, processing, storage, transport and logistics and retail. Secondly, backwards to the input suppliers of the farm operation (farm inputs), including fertiliser, seeds and various components of the feeder supply chains. Feeder supply chains provide inputs to both pre-farm production and post-farm production parts of the supply chain and include AgTechs, Public Infrastructure, Research and Development, Financial Services and Other Services (e.g., agronomy).

It is important that the AADX considers the whole of the agricultural supply chain, not so much to develop a whole of supply chain solution, but to understand the broader impact of an AADX. This finding is also supported by DXs interviewees:

> "Any data solution needs to encompass the entire supply chain, because that's where you'll derive the benefits [...] because he's got provenance and he can show what's happened to stuff, and that's got to be worth some value, right." (DX Interviewee)

> "We need to bring all the companies along the agricultural value chain to have the possibility to join and that was the reason why we made a change on the entry model [...] In the history [sic] only machine manufacturers could become a shareholder, that has changed and now every company along the agricultural value chain can become a shareholder or a business partner." (DX Interviewee)

The role of AgTechs in the agricultural supply chain

The AgTech vendor space includes a range of actors from Small and Medium Enterprises (SMEs) to global enterprises. While SMEs often focus on-farm, they also play a key role within the larger supply chain. The role of the SME is particularly notable in driving innovation and leveraging the demand for technology, for example, in achieving the UN Sustainable Development Goals. Nevertheless, large global enterprises continue to play a significant role—for example traditional farming sector players such as John Deere with Operations Centre—as well as 'big tech' such as Microsoft with Farmbeats.

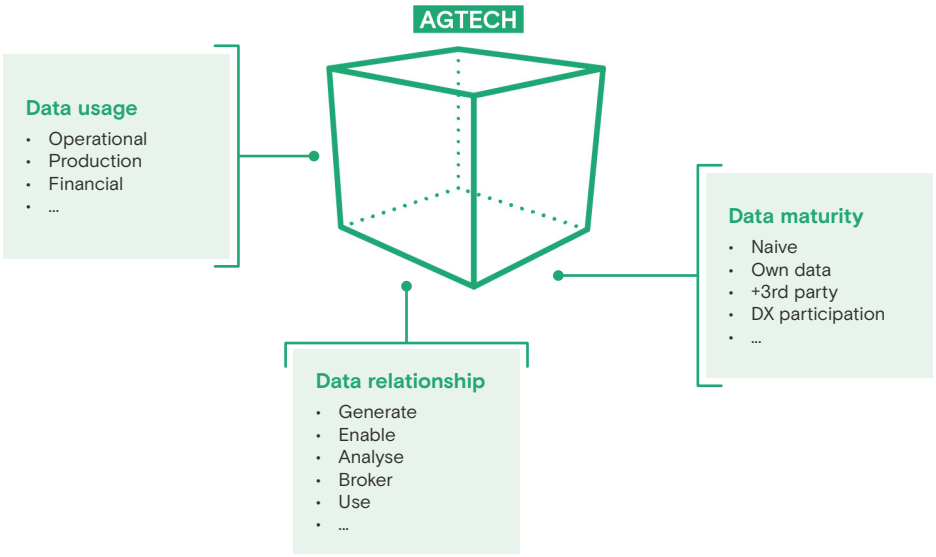
The Internet of Things (IoT), Blockchain, Big Data Analytics and Artificial Intelligence (AI) are important aspects of technologies across the supply chain and speak to the crucial role of AgTech in enhancing productivity. However, while AgTech is crucial to improvements along the supply chain, it is important to understand that they represent only one component of inputs. While the AgTech vendor may be well placed to facilitate the collection of data, it is not clear that they offer the best point for realisation of a DX value and its return to the farmer. Therefore, the centring of AgTech in an AADX is not recommended, but rather an ecosystem approach should be taken to foster a dynamic and open data exchange community.

Other actors may be key to realising the value that will result from any data initiative. For example, the financial services industry face ESG targets that establish strong value for sustainability data over the agricultural supply chain and offers a potential means for farmers to realise value through, for example, preferential loan arrangements. Similarly, food processors may benefit from understanding the provenance of their inputs from planting through to delivery to their facility and may return a premium to farmers for such inputs. In short, an AADX should be open to unlocking the benefits of data without wedding itself to an idea of who the beneficiaries are or what the benefits may look like.

AgTech ecosystem

The Australian AgTech ecosystem is internally diverse. Indeed, the Australian Bureau of Statistics (ABS) names 17 categories within the agricultural sector, all of which may be serviced by various AgTechs. In our study we identified over 80 non-exclusive categories describing the services AgTechs may provide.

By exploring the online AgTech directories AgTech finder and Ausagritec, we identified 356 AgTech companies. While this may not be an exhaustive list, it does represent a significant number of the major AgTech firms in Australia. However, to the best of our knowledge, there is no conceptual model that describes AgTechs with respect to how they interact with data. Knowing how AgTechs interact with data enriches our understanding about their data relationships and requirements. As such, we conceptualised a three-dimensional space describing the interaction of an AgTech with data in Figure 2.



Agtech can be considered across a three dimensional space describing the relationship of an organisation to date: both its own and that of third parties.

Figure 2 Conceptualisation of AgTech data ecosystem

In this conceptualisation, data relationship refers to an AgTech's role in generating, enabling, analysing, brokering and using data; data usage refers to an AgTech's data usage such as for operational, production, financial and other purposes; and data maturity refers to whether an AgTech is naïve about data, conscious of the data they own, or whether they integrate and utilise data. This conceptualisation informed the design of the business and data section of the survey questionnaire to capture AgTechs' current, and aspirational interaction with data (See Appendix A3). Beyond informing the questionnaire design in the survey, this model can be further developed to inform the variables that should be measured and assessed in defining the uptake of an Australian agricultural DX.

The following survey data and analysis presents demographic information captured in the survey sample (n=32), and shows the variability represented within the sample. Overall, two-in-five participants (40%) have been in the industry for 10 or more years. A large segment of the sample represented those in managerial or c-suite positions (65%), with participants also representing other roles like Account Executive, IT Consultant, Digital Consultant, Strategic Advisor and Data Scientist. Key demographic information, such as experience and the roles of participants, indicates an ability to comment authoritatively on the subject matter. Table 1 summarises the demographic information of the survey respondents.

Table 1 Demography of survey respondents

Characteristic	%* (*rounded up)
Age	
18 - 24 yrs.	3
25 - 34 yrs.	3
35 - 44 yrs.	22
45 - 54 yrs.	44
55 - 64 yrs.	25
65 + yrs.	3
Gender	
Male	84
Female	16
Duration in AgTech industry	
Less than 12 months	3
Between 1 and 3 years	13
Between 3 and 5 years	22
Between 5 and 10 years	22
Between 10 and 15 years	9
More than 15 years	31
Role within the business	
Founder/CEO/Owner/COO	35
Manager	22
Chief Technical Officer	8
Technical developer	11
PR/Marketing/Advertising/Sales Manager	0
Other (please specify)	24

Table 2 summarises the business characteristics represented in the sample. The results show the diversity of businesses in terms of their size (i.e., number of employees, turnover) and their collective experience (i.e., number of years in operation). This, in our view, provides a good representation of the range of AgTechs in Australia. It is not surprising to note that more than half of the participants in this survey reported that they worked for a business that has been in operation for 10 years or less. This seems consistent with the historical rate of development and adoption of data-driven technologies, including cloud infrastructures that have proliferated start-up businesses in the last 10-15 years.

Table 2 Characteristics of businesses of survey respondents

Characteristic	% (*rounded up)
Number of employees	
Less than 20 people	38
20-100 people	38
101 or more	24
Duration of operation	
Less than or equal to 10 years	54
10 to 20 years	22
More than 20 years	25
Annual turnover	
Less than $500,000	13
Between $500,000 and $ 1 million	3
Between $ 1 million and $ 5 million	25
Between $ 5 million and $ 10 million	16
Between $ 10 million and $ 20 million	16
Between $ 20 million and $ 50 million	3
Between $ 50 million and $ 100 million	0
More than $ 100 million	22
Prefer not to say/Don't know	3

AgTech survey respondents were classified based on the sectors in the ABS Australian National System of Accounts. Figure 3 illustrates the distribution achieved. Most participating businesses were found to be associated with the AgriTech services and solutions (75%) and the Software/IT sectors (72%).

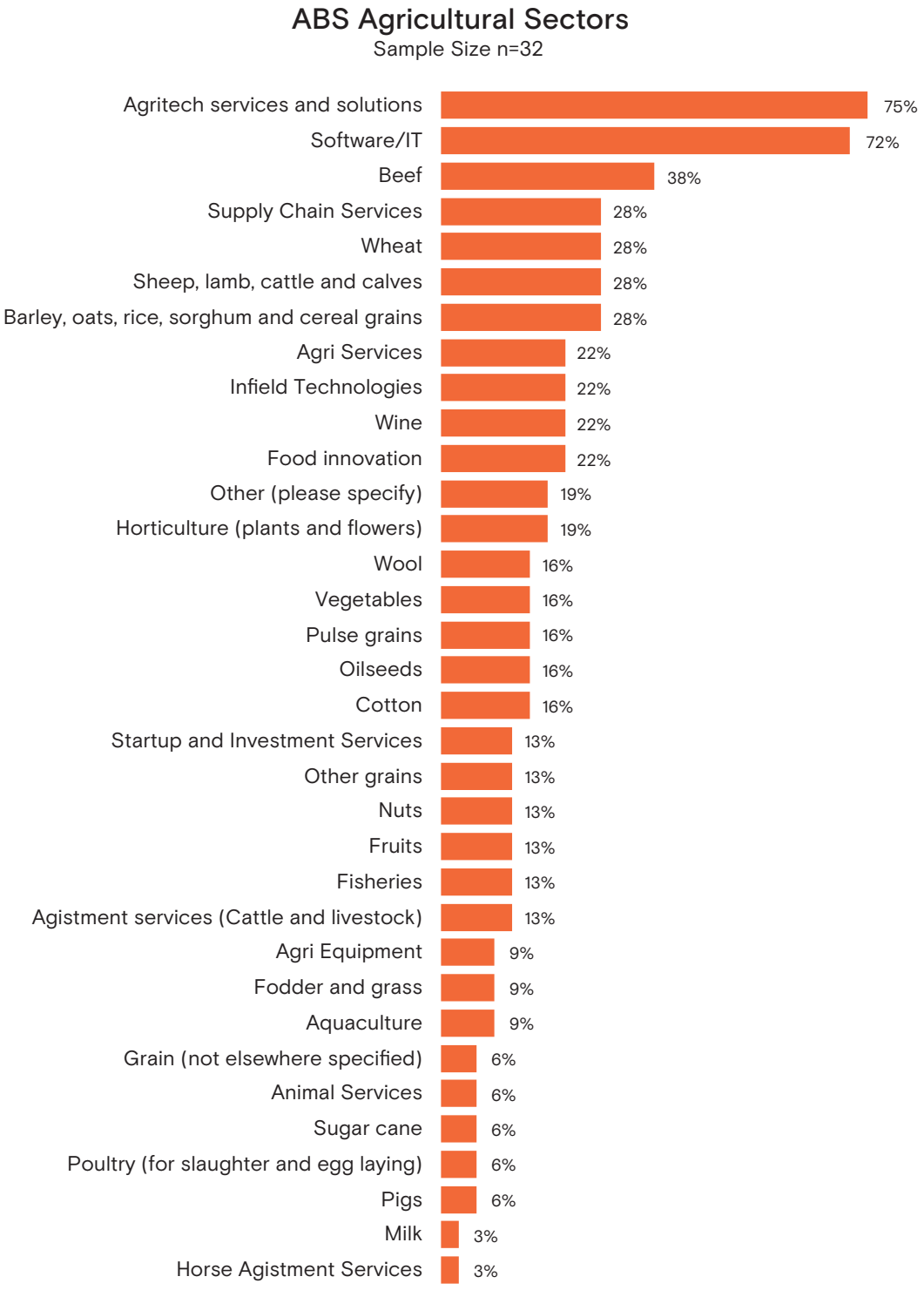


Figure 3 Survey respondents according to ABS agriculture sectors

To further contextualise the AgTechs within the broader Australian agricultural industry, respondents were also asked to nominate the type of service they offered. Figure 4 summarises the distribution of responses received. More than two-thirds of the total participants (72%) provided Software/IT Services within the Agricultural sector, followed by Supply Chain Services (28%). "Other" areas mentioned were Research and Development and Traceability.

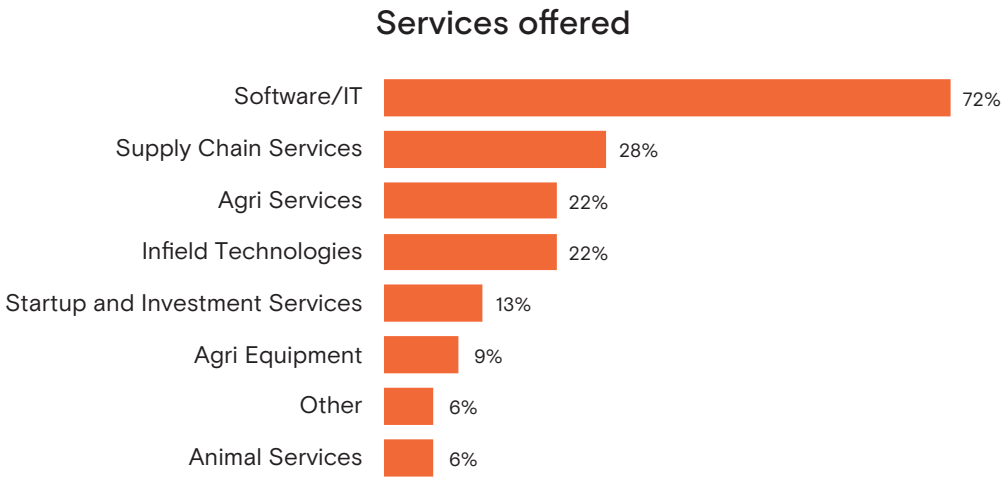


Figure 4 Services offered in the agricultural sector by survey respondents

To develop a baseline understanding of AgTechs' self-reflected views on their businesses, survey respondents were asked to evaluate their strategic business performance. Overall, 92%[4] of businesses were satisfied with their current strategic business performance comprising their relationships with external stakeholders, financial performance and ability to positively respond to challenges posed by competitors. This was particularly the case with external stakeholder relationships, where 97% indicated, they have continued to build strong relationships (see Figure 5). The results show that the Australian AgTech sector is conscious about building strong relationships and improving their financial position even in competitive environments. This would likely feed into a broader data sharing community, should an AADX become available.

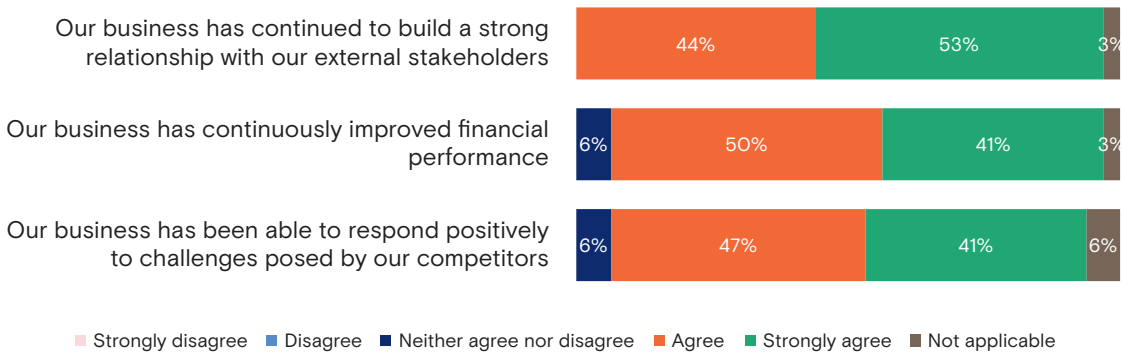


Figure 5 Strategic business performance of survey respondents

4 Derived from the average of percentage of the responses to the three factors in Figure 5 corresponding to Agree/Strongly Agree.

This section of the report has shown that the Agricultural supply chain is complex and that AgTechs play an important role within this supply chain. The above characteristics paint a picture of an Australian agricultural industry underpinned by Small and Medium Enterprises, with a predominance in software/IT services. The survey data (Figure 5) also suggests that the AgTech respondents are already engaged in strong relationships with external stakeholders, which may translate into an affinity for greater data sharing, should a DX infrastructure be available. The AgTech ecosystem model also suggests that understanding the interaction of AgTechs with data can yield insights and greater understanding of opportunities for an AADX, as well as barriers to its adoption. This is further analysed in the following sections.

2.1.2 Data as a commodity

The commodification of data is driving the establishment of a new global economic system, the data economy. Despite this development, it should be understood that data alone does not create social or economic value (PricewaterhouseCoopers, 2018). Rather, the ability to economise on data is beset by a persistent challenge: the lack of a standardised means for valuing data, which results in most data being unmeasured, mismanaged and underutilised (World Economic Forum, December 15, 2021). Part of the difficulty in measuring the value of data is its unique nature as an asset. That is, value is linked not to a singular piece of data, but to how it is combined and the distinct insights that this gives rise to.

The value of data also depends on how it is used, and the scope of its utility ranges from raw information to its interpretation leading to new understandings and actionable insights. Indeed, it is the transformation of data into information and knowledge that creates value in data. Data value is also affected by quality and relevance over time, context and applicability, and costs associated with protecting it—the more sensitive the data, the higher the associated security risks and costs (World Economic Forum, November 2021, p. 5). Intended use cases also impact the value of data and should be carefully considered (World Economic Forum, November 2021, p. 3). In this sense, stakeholders shape the worth of data, depending on the uses to which it will be put and its expected benefits.

Linked to the fluctuating nature of data economics is the problematic reduction of its value to monetisation, which undermines the actual and potential value of data. Recognising this complex economic terrain obliges a widening of the view from the monetisation of data to one in which the flow of data enriches whole supply chains and entire industries. What is needed is a more collaborative approach to data exchanges, as well as a broadened understanding of the potential of data to directly and indirectly "improve business operations, strengthen government relations, address cybersecurity concerns, enhance brand reputation, tighten customer relationships, and engage with local communities" (World Economic Forum, December 15, 2021, para. 11). A transformation of our relationship to data and our understanding of its value is needed to unlock the true potential of data sharing.

Data value

In agriculture, the complexity of standardising the value of data is preventing its more widespread exchange. Reticence towards data sharing by data producers stems from the fact that many farmers do not see a benefit in sharing their data. This hesitation can and should be overcome by demonstrating the value for them in doing so and ensuring that they share in the benefits:

> "[…] there's a reticence, but the message that I take – the positive thing is if you can demonstrate to me that there is generally value in me letting you have data then you [can] have that data […] But it's really a problem, you have to demonstrate that value to them." (DX interviewee)

> "So, some farmers think they will be selling their data undoubtedly […] It's just my hunch is that it's not – there isn't enough value in the system for an individual farmer to see enough financial benefit from it to encourage them to share data […] how does the farmer get value out of their data? […] it's by the return of insights, rather than necessarily financial value." (DX interviewee)

Despite the complexities of an emergent global economy and the problem of monetising individual datasets to benefit data producers, those in analytics clearly understand their worth as they base their business upon it. AgTechs too, clearly see value in data. This is evidenced by how much attention AgTechs are placing on data governance, management and analysis processes.

The survey asked about existing data governance, management and analysis processes. Respondents were allowed to select more than one choice. A total of 84 responses were collected (Figure 6). Overall, more than two-thirds of respondents indicated they had documented processes for ensuring compliance with regulatory frameworks (72%) or assuring data quality (78%). Those remaining utilised some ad-hoc processes to manage data governance or analysis, while only 12.5% of all survey respondents had no documented processes.

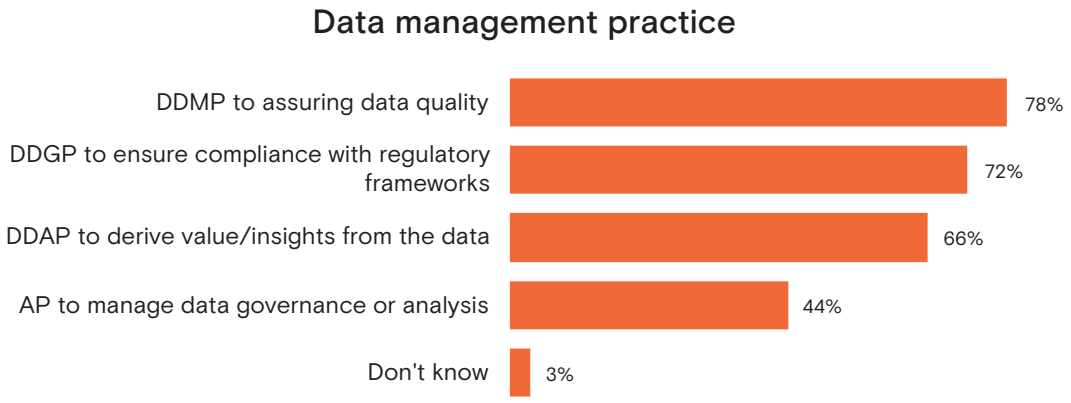


Figure 6 Data management practices by survey respondents[5]

5 AP: Ad-hoc processes to manage DG or analysis; DDAP: Documented data analysis processes; DDGP: Documented data governance processes frameworks; DDMP: Documented data management processes.

The survey results suggest that data is broadly perceived as valuable. Yet while there is a strong impetus for proper data management practices, there are also various AgTechs that lack good governance or that are inconsistent with their data management practices. It is important to note that inconsistency is not solely the result of technical inability, but reflects the current, disparate state of data sharing. Whether it is in providing a formal means for valuating data or encouraging collaborations in projects of common interest, it seems an intermediary such as the AADX could play a critical role in fomenting a culture of standardised data sharing practices that could re-shape the industry.

2.1.3 Data sharing

The globalisation of food production makes international borders an integral aspect and significant challenge for data sharing. Moreover, growing scrutiny by regulators and consumers alike requires transparency along a complex global supply chain, which can only be ensured through data sharing.

> "Having that ability to share the data, track the data, know what's gone on up and down the supply chain is key, and I think that's the international piece." (DX interviewee)

As mentioned, the lack of a standardised means for valuing data is an impediment to data sharing and one of the major challenges facing the consolidation of a data-driven economy. Part of the problem is that the difficulty in measuring the value of data can mean that individual data points are not seen as valuable, and therefore data producers do not benefit monetarily from data sharing. This creates the perception that others are benefiting economically from their data while data producers (e.g., farmers) receive nothing. Where individual data may not attract significant monetary value, benefits from insights gained from that data must be returned to data producers, particularly farmers, in one form or another. Where this fails to occur, farmers and other relevant stakeholders will likely remain unwilling to share data.

The Data Exchange ecosystem

What a DX is and does is neither well-defined nor well-understood. This creates ambiguity and results in miscommunication amongst stakeholders. The lack of clarity around the meaning and purpose of a DX also gives rise to mistrust between stakeholders. This is further exacerbated where there are power discrepancies, for example, between individuals and companies, between small enterprises and corporations, and between private actors and public institutions. In this report, we provide an outline of a DX definition as an important step in avoiding ambiguity and situating views expressed by survey and interview participants.

It is not useful to think of a data exchange as an object or a place, in the manner for example of the stock exchange. Rather, data exchange can be considered as a verb, the act of data exchange, and as a noun, the place where data is exchanged. Another way of thinking about it is that data exchange involves the seamless transfer of large files between individuals or organisations, and a data exchange platform is the software, hardware and governance that facilitates such exchanges. Establishing this difference and illustrating it for stakeholders is important to arrive at common ground in any proposed data exchange initiative.

There are a range of understandings of what a data exchange is and what its potential impact would be if one was introduced to service the Australian agricultural sector. Our research finds a disconnect between those promoting a data exchange and the perception of its intent by its anticipated users. Without a common understanding of data exchange, the potential for mistrust and suspicion is increased and with it, the risk that resistance will become entrenched.

Data exchange
can be considered as a verb,
the act of data exchange,
and as a noun, the place
where data is exchanged.

For the purposes of our research into AgTech vendors we used the following definition of a data exchange, which we synthesised from grey literature and the DX interviews:

A Data Exchange may be considered as a platform that facilitates the secure and controlled dissemination, acquisition, sharing and integration of datasets, to create business value for the producers and the consumers of the data.

Data exchange may occur as peer to peer sharing of data between or within entities; private data exchange within an industry vertical or functional area; or within an open data marketplace. Participants can decide how much data they share and use, and how often they share and use.

Such a platform may support Ag businesses by providing access to quality, traceable and secure data to inform decision-making.

This definition allows for a degree of variability in the way in which a data exchange is established and the services it offers to the market whilst recognising core attributes and services.

This research found a common perception among AgTechs that the current AADX initiative would involve a full public exchange of data in which curated datasets, incorporating their customer's data, would be offered for sale to all, including AgTechs. There was strong resistance to this concept of data exchange because it was seen as competing with the AgTechs in their own markets. On the other hand, even the idea that the AADX would provide data sharing infrastructure without adding value was found suspicious and unwarranted by some AgTechs, who were of the view that APIs with tokens are already sufficiently serving their needs.

This variability in understanding of a DX was also seen in the survey data. Given the generic description of a data exchange platform, survey respondents were asked to indicate if they were currently engaging in a similar system. Overall, 56% indicated that they were not (See Figure 7), with only five of the participants indicating that they participate in both Australian and overseas data exchanges. Australian data exchange platforms mentioned by the respondents include Aveva datahub, Eratos, Australian National Soil Information System, Agricultural Research Federation, Meat and Livestock Australia Product Integrity databases, public websites, and some other data exchange platforms managed by their own industries (via SharePoint and Teams). Overseas data exchange platforms mentioned by respondents include Aveva datahub, Pure Farming, JoinData, Proagrica, Agrimetrics and Teams folders, which are shared with international collaborators.

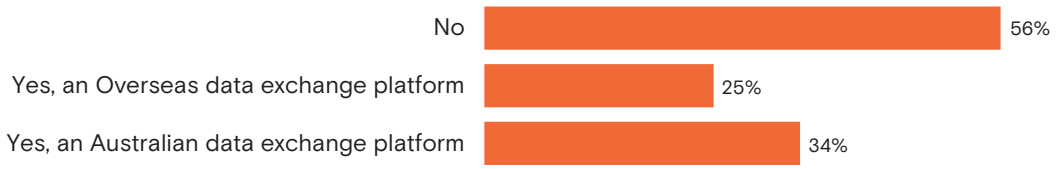


Figure 7 Survey respondents engagement with existing data exchange platforms

The platforms mentioned by the AgTechs in the survey data indicate a diverse understanding of what a DX is and does. These diverse views reinforce the need for establishing a clear working definition of a DX that will respond to the actual needs of the industry, as intimated in the survey responses above. As such, we offer a framework for conceptualising a DX below.

Conceptualisation of a data exchange

Based on the views of a data exchange and the relevant data sharing needs expressed in our primary data, we have designed a conceptual framework for a DX. This framework is designed to account for the variability in the understanding of a DX. It reflects an ecosystem comprising platform and services of varying function and complexity, as shown in Figure 8 below.

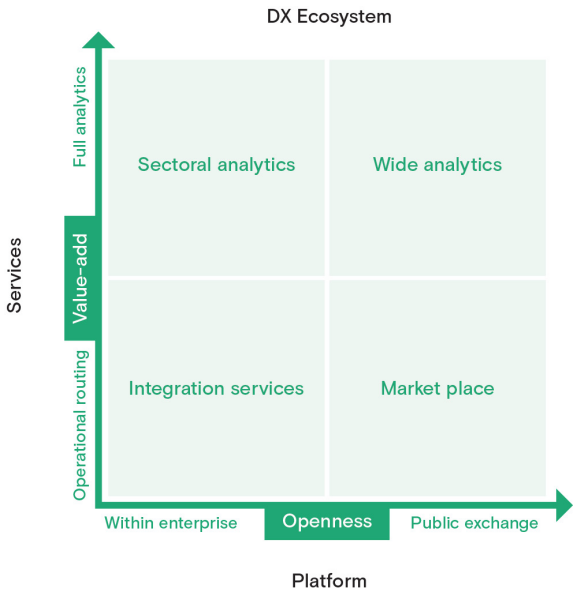


Figure 8 The DX ecosystem

Within the DX ecosystem, the platform and associated services exist over non-discrete contiguous ranges. Considering the platform dimension, at one end, data exchange may occur within a single enterprise and support the provision of a whole of enterprise view through the integration of various endpoints. At the other end, the data exchange may be a completely open public platform offering aggregated and curated datasets either freely or for purchase. Considering the Services dimension at the one end, simple integration and data sharing may occur through APIs at various end points and intermediate systems, or through a simple dedicated data pipeline service. Along this axis, additional services from standards validation and quality control, through to full data analytics may be offered.

Integration Services address the need for data to be made available across multiple systems and products within an enterprise or closely defined sector, with little or no services added, based on controlled and restricted access.

Sectoral Analytics provide a wider degree of analytical services while restricting access to within an enterprise or a closely defined sector.

Market Place defines a limited value-add service in which data is open and publicly available, such as a data mart.

Wide Analytics describes publicly available data, offering a high degree of analytics, and value-add services.

It should be noted that these are not mutually exclusive concepts and that actors may start in a particular position and move as the market develops. For example, an AgTech vendor providing services to a farming enterprise simply integrating a range of endpoints into a single view of the farm through published APIs is consistent with this DX Ecosystem. As their market develops, the AgTech can expand their offering across a particular sector or locality to add value by aggregating data, while remaining consistent with the ecosystem described. Similarly, industry level quasi-governmental bodies or private enterprises can begin to aggregate datasets and provide these in an open exchange for public offering, while remaining consistent with this ecosystem.

This ecosystem model encompasses the full range of interests encountered over the course of our study. We found that AgTech stakeholders were asking for a DX ecosystem in which stakeholders can choose how and when to participate. This ecosystem incorporates the interests of both commerce and government and provides a framework for the common standards and controls that are in the interests of all, without constraining commercial interests.

A range of existing DX's are shown within the dimensions described in Figure 9, based on publicly available information.

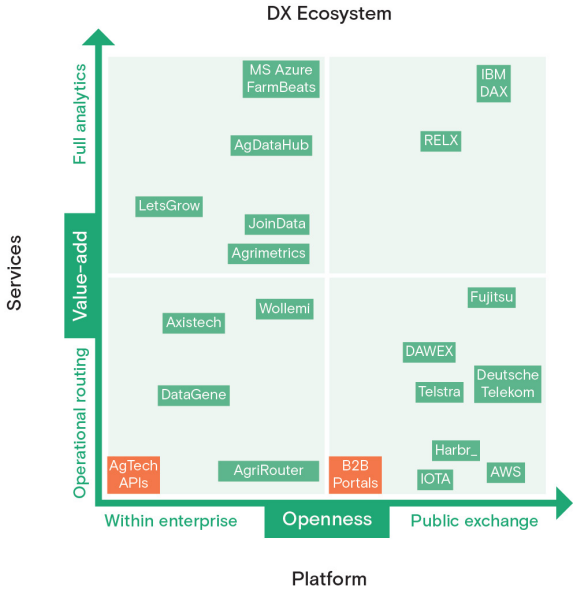


Figure 9 Populated DX ecosystem

In considering how prepared Australian AgTechs may be to participate in a DX should they be inclined or induced to do so, we sought to understand the adaptability of their businesses to digitalisation. To explore their ability to integrate with the proposed AADX, survey respondents were asked to evaluate the adaptability of their current business practices. Overall, 72% believed their business is adaptable (agree/strongly disagree). More than half (57%) indicated an interest in adopting a data exchange platform as soon as it was available in Australia (See Figure 10).

72% BELIEVE THEIR BUSINESS **IS ADAPTABLE**

57% **INTERESTED IN** ADOPTING A DX IN AUSTRALIA

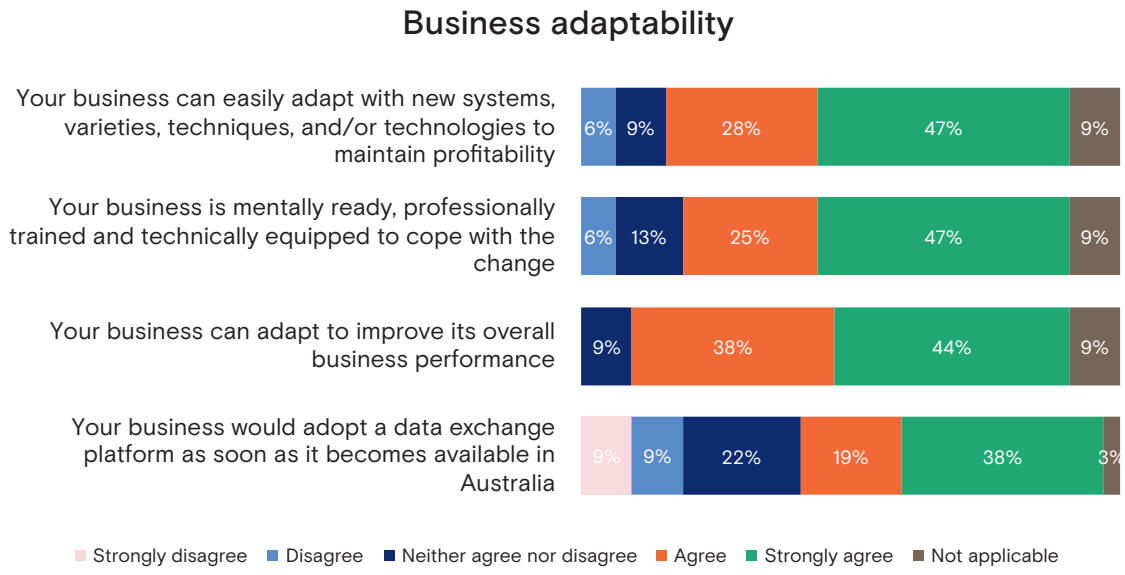


Figure 10 Business adaptability of survey respondents

2.2 Summary of Key Findings

This section analyses the key background concepts regarding the nature of the agricultural supply chain, the challenges in valuing data and current data sharing issues and practices. Below are the key findings from our research.

- The agricultural supply chain is relatively more complex than other supply chains. The supply chain incorporates farm inputs, on-farm and post-farmgate activities and includes the physical flow of commodities and value-add services. The impact of data sharing in any one sector of the supply chain can have significant impacts on the rest of the supply chain. **To encourage the broadest possible range of stakeholders to participate and for the benefits of data sharing to impact the whole supply chain, it is important to understand the breadth of their needs and the diversity of their views on DXs.**
- AgTech play a significant role within the agricultural supply chain. They leverage demand for technology and drive innovation. However, in such a complex supply chain, it is not clear from our research the extent to which AgTechs play a key role in realising the value of a DX within the agricultural supply chain. **It is important that other supply chain actors such as farmers, and retail, financial and insurance sectors are also considered in tandem with the role of AgTechs to better understand how and where utility can be derived from within the supply chain.**
- AgTech is a broad term that, simply speaking, could be defined as entities that provide technology services to the agricultural supply chain. AgTechs are diverse, with more than 80 identified, non-exclusive categories based on services provided. Within the context of data sharing, three factors are important in their classification: (1) data usage; (2) data relationships; and (3) data maturity. **These variables should be measured and assessed in defining the uptake of an Australian DX.**
- The AgTech community appreciate the value of data as evidenced in their current data practices, however inconsistencies in their data practices indicate an opportunity for the sector to improve and fully leverage the value of data. **It is expected that a DX will play a critical role in facilitating data sharing and fomenting a culture of standardised data sharing practices.**
- The value of data as a commodity is difficult to evaluate in terms of monetary value since it cannot be reduced to a singular data point but changes depending on how it is combined to produce insights, among other variables. **The value of data should be determined based on the point within the supply chain where it is being valued, the purpose to which it is put, and by the relevant stakeholders themselves.**
- Data sharing occurs within the agricultural supply chain on various levels. There are no agreed upon terms of reference for data sharing. This leads to a very diverse perception of what a data exchange is. **To arrive at a meaningful consensus on a data exchange, consistent terms of reference must be defined, particularly with regards to the openness and value-add scales proposed in this report.**
- 72% of survey respondents indicated they had the ability to adapt to an Australian agricultural data exchange while 57% of AgTechs indicated a strong interest in adopting an Australian agricultural data exchange as soon as it were available. **This indicates that a sizable digital community of AgTechs lies in waiting, should a DX become available. However, more needs to be done to understand the apprehension from the remaining AgTech community.**

3 The Data Exchange Opportunity

“The ultimate goal of data exchange should be to create an open data system where data sources can be combined in the end by consumers of data on behalf of the farmers.” (DX Interviewee)

Around the world, agriculture is increasingly reliant on, and benefitting from, data-driven insights to solve common and complex problems. For example, applications are seen in precision agriculture where data and data sharing are playing an increasingly important role in minimising harmful inputs and reducing resources, and in sustainability initiatives, where data is increasingly important in the measurement of carbon sequestration for the carbon credit market.

European countries such as the Netherlands are exemplifying how data can be used to increase production, lower environmental impacts and contribute to land regeneration, all while adding value to products through technological innovations and by demonstrating ethical and sustainable practices (KPMG, 2018, p. 8). Collaboration and innovation with non-interventionist government support is driving the Dutch national commitment to sustainable agriculture with considerable value-add to the industry. In fact, technology and Intellectual Property is “the single largest segment of Dutch agri-food export earnings” (KPMG, 2018, p. 2). The opportunity to produce greater quantities of quality, ethical and sustainable food on smaller patches of land thanks to agricultural technology depends on healthy data sharing practices and a collaborative attitude. Technology companies collaborating with farmers, such as JoinData, are at the forefront of these advances.

Similarly, in a multistakeholder collaboration, the World Economic Forum’s Centre for the Fourth Industrial Revolution, has identified how emerging technologies such as Artificial Intelligence (AI), blockchains, drones and the Internet of Things (IoT) can be harnessed to increase productivity and incomes for farmers, reduce waste and enhance supply chain efficiency and transparency (World Economic Forum, March 2021). The success of such innovations depends on the flow of data and multistakeholder approaches that lower barriers and create opportunities for data sharing.

While the Australian agricultural sector has made serious strides in utilising and sharing data for the benefit of the sector, there are further opportunities to be realised. This section of the report will explore some of the opportunities and the challenges in realising those opportunities, as well as the priority areas as seen from the Australian AgTech sector’s perspective, and from the experience of existing agricultural DXs interviewed for this study.

3.1 The Research Findings

The research identified three broad opportunity areas: (1) data sharing and management; (2) data quality; and (3) data-driven innovations.

3.1.1 Data sharing and management

The research indicates that data sharing and management are clear areas for improvement in agriculture, and that opportunities lie in providing secure and efficient data transfers and integration services.

Data used by AgTechs may arise from different points in the agricultural supply and value chain. These agricultural data are often generated from on-farm operations that are often dispersed, both geographically and technologically. That is, farm data may be spread over multiple digital and paper systems and stored in different technological and geographical realms. This often leads to disaggregated data siloes, held by individual agents with whom the farmer interacts, such as fertiliser suppliers, irrigators, agronomists and accountants. As our interviewees attest:

> "[The farmer] will run off to their fertiliser companies to say here, you digitise my fertiliser records, then they run off to their irrigation company and say, here, you digitise my water, and they go to somebody else and say, here, you digitise my payroll [...] and now they are still living with the problem of non-standards [...] The farmers have given away their power one teaspoon full at a time [...] they've lost control of the non-standards based systems. [The farmer] shouldn't have disaggregated in the first place [...]" (AgTech Interviewee)

One interviewee described the problem of disaggregation as being exacerbated by the lack of deep penetration of Enterprise Resource Planning (ERP) systems into farms:

> "The average farm has like [...] up to 19 or 20 digital systems. The average food processor has 35 digital systems. So, the problem with all this stuff, is that they don't even know where their data is, they can't track it [...] the reality is most of these guys are still using 10 to 30-year-old ERPs, they're still using four different things for farm management including lots of Excel sheets. And so that's where the challenge comes in." (AgTech Interviewee)

The survey verifies this tendency, where the trend of disaggregated data seems clear from the number of different external parties with whom a single AgTech business shared data. 50% of the participants in this study reported sharing data with 21 or more external entities (Figure 11). 94%[6] of participants indicated that their business shares data with others. Further, 97% of participants viewed insights generated from data as part of their business practices (see Figure 12 below).

50% REPORTED SHARING DATA **WITH 21+ ENTITIES**

94% INDICATED THEIR BUSINESS **SHARES DATA**

97% **VIEWED DATA INSIGHTS** AS PART OF BUSINESS PRACTICES

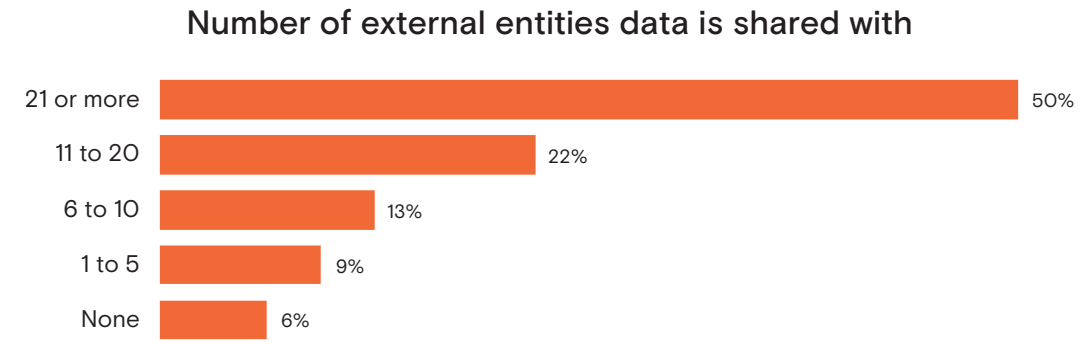


Figure 11 Number of external parties that survey respondents share data with

Figure 12 Data practices of survey respondents

6 Based on the number of participants who shared data with at least one other external party.

In sharing data with relevant parties, API/secure file transfer sites is noted as the most popular method amongst survey respondents. This is followed by data sharing via emails or sharing sites (See Figure 13). Other data storage and sharing methods mentioned include SCADA, OT centric Data Stores, Eratos Gateway Nodes and the Eratos Platform, web services and direct repository interconnects. This demonstrates the diversity in how data is shared amongst AgTechs and the potential for a coordinated DX to meet these needs more efficiently.

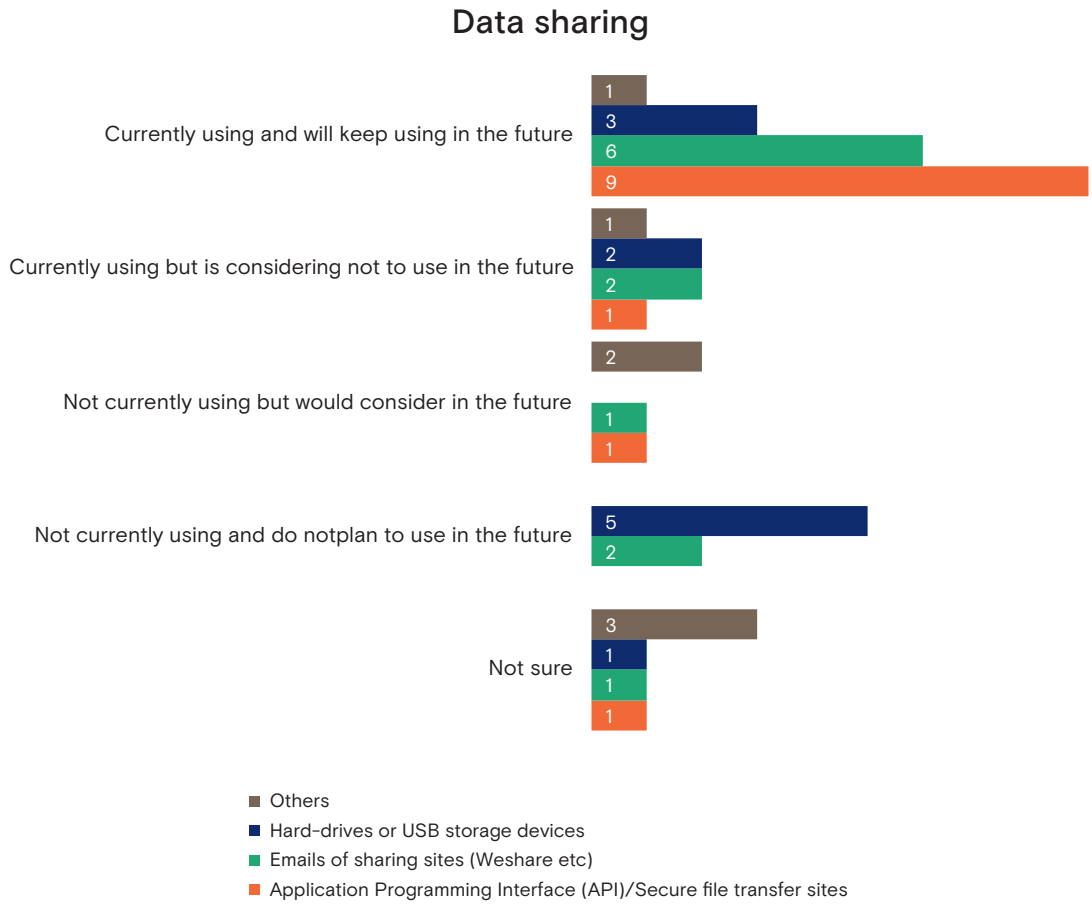


Figure 13 Survey respondents data sharing methods

When asked to evaluate inbound and outbound data distribution practices, 67%[7] of respondents indicated that they were satisfied/very satisfied, while 11%[8] reported being dissatisfied. 75% reported their outbound data distribution was well planned, efficient, safe and secure. However, only 59% agreed that this was the case with their inbound data integration (See Figure 14). These results indicate that there are opportunities for improved data distribution and data integration, which a DX should look to provide in this space.

7 Derived from the average of Agree/Strongly Agree for both inbound and outbound data practices.
8 Derived from the average of Disagree/Strongly Disagree for both inbound and outbound data practices.

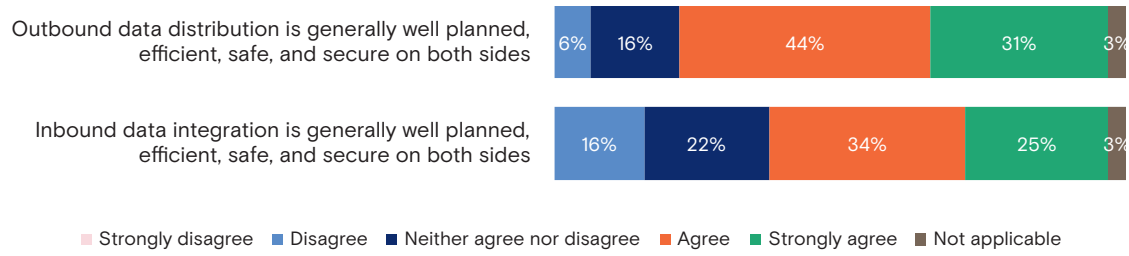


Figure 14 Outbound and inbound data integration practices

The DXs interviewed articulated their understandings of the purpose and function of a DX. This has been succinctly put by DX participants as follows:

> "The ultimate goal of data exchange should be to create an open data system where data sources can be combined in the end by consumers of data on behalf of the farmers." (DX Interviewee)

> "In those two-sided data marketplaces, you can be data providers and/or data acquirer [...] you can be both by the way [the idea is to] help data circulate." (DX Interviewee)

The following key points on data integration, standards and interoperability, and diverse industry needs can be inferred, as discussed below.

Data integration

While there has been a tendency for agricultural sector data to exist in functional islands, increasingly the requirement is for on-farm data to be consolidated to provide whole of farm views that can generate insights. AgTech companies seek to provide their data to the farmer in a manner that will add the most value, contributing to integrated insights into the farm operation. This raises a requirement for the AgTechs to integrate their product with other products across the AgTech ecosystem. As well as collecting their own data, AgTech products will often make use of third-party data, such as rainfall and soil data, to perform the analysis they provide to farmers.

Similarly, the farmer has a requirement to share their data, either within the farm or third-party function providers such as agronomists, fertiliser companies and business support. Here, a potential challenge for the farmer is knowing what data they have and where that data sits. As one DX interviewee reflected:

> "I suspect 90% of all grain harvest data is still sitting on a harvester because the farmers just don't know what to do with it or have no interest. And so it is, it's an industry wide sort of a challenge."

The degree to which agricultural data and other sector data are siloed from one another is unclear. However, it seems that if agricultural data itself is siloed and dispersed, then it can only be the case that the industry is not well connected to other sectors in terms of data. In part this is likely due to the costs associated with data management and the lack of integrated systems:

> "It costs farmers time and money to manage their data. Or they end up paying someone else to do it for them. The last thing you want as a farmer is different systems. You want easy-to-use, integrated systems so you don't have to type something into one system once and then input it somewhere else." (Gleason, 2022)

The question arises as to how these growing points of integration can be serviced efficiently, securely and in a manner that is both cost effective and timely, while allowing the farmer to retain control of their data. At present, data sharing is a matter of knowing who holds the data:

> "We are authenticating effectively across platforms and then we are sharing data and services across platforms with the producer's authority through API keys and tokens and coupons. So, I think one bit is basically knowing who the person is, and then the second bit is giving that individual the ability to share information across platforms with third parties." (AgTech Interviewee)

The use of APIs with security authentication features such as tokens appears to be widespread amongst AgTechs. While this may meet the immediate and present needs of those requesting and sharing data, widespread use of APIs may be a limitation as systems scale and integration demands become more complex. Herein lies the potential of data integration to overcome silos and enhance collaboration among and across industries and borders. Integration has potential cost and time savings, which will encourage farmers to share data as it will minimise their work in entering the same data into multiple systems. Facilitating data integration presents an opportunity for DXs to contribute positively to the sector.

Standards and interoperability

Interoperability is the cornerstone of data integration. If machines and software are not interoperable, the data they generate can be more challenging to integrate. Interoperability requires the consistent application of standards and ontologies across the agricultural sector. While some standards exist to ameliorate the issues of a lack of interoperability, there are some concerns around the consistent use of standards. In particular, standardisation is seen to be too permissive and plagued by different interpretations and implementations. This point has been highlighted by precision agriculture company, Aspexit (2021), with regards to a perceived gap between theoretical ISOXML certification by the Agricultural Industry Electronics Foundations (AEF) and practical interoperability challenges faced by software developers:

> "Let's take the example of ISOXML. This standard was originally set up by manufacturers. It was only later that software editors were integrated into work groups. The design of the standard is therefore not 100% adapted to the problems faced by software editors, particularly on the issue of traceability. For example, the exchange of tasks (crop operations) between a farm management information system and a machine is not as simple as that. On a terminal, for example, it is possible to carry out an operation without attaching it to a plot of land. If no identifier has been assigned to a plot, it will therefore not be possible to trace everything that has been done during the cultivation operation."

Indeed, the survey data suggests that respondents use different technologies to manage data storage. Overall, respondents demonstrated a greater reliance, and intention to adopt digital approaches (digitised filing systems and database systems), compared to hard copy filing. Over three quarters reported using digitised filing (76%) or database systems (84%). Other approaches to storing data appeared to be virtual in nature and included data lakes and enterprise data warehouses (See Figure 15). The range of different technologies used highlights the importance of adopting data standards to achieve interoperability and data integration.

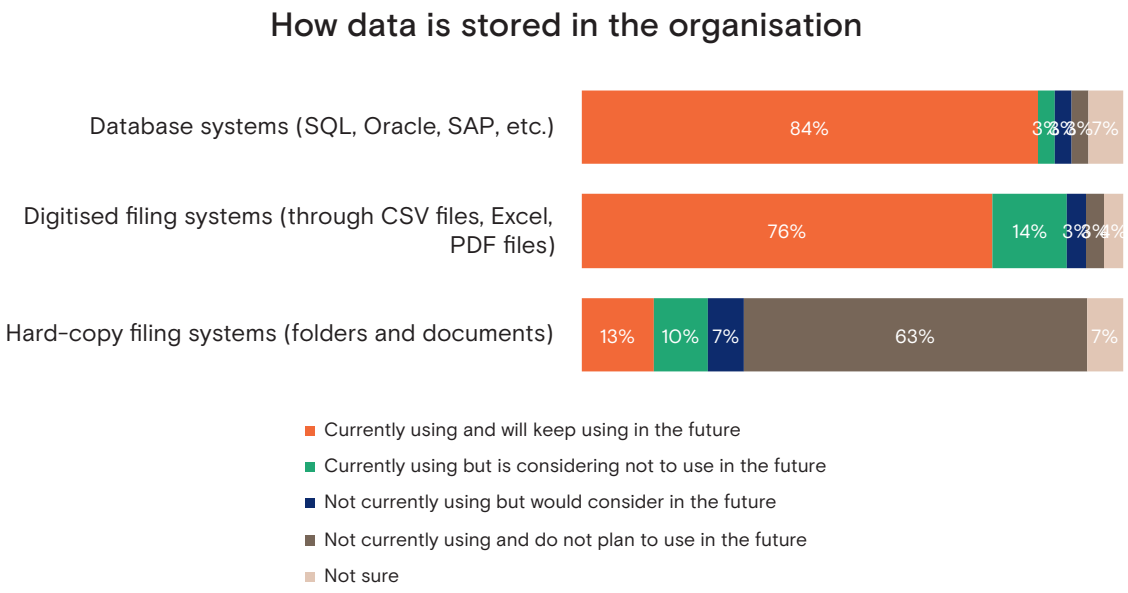


Figure 15 Data storage practices amongst survey respondents

Technologically, interoperability is not always simple. Aspexit (2021) holds the view that standardisation should not take a one-size-fits-all approach but be tailored and applied based on use cases. This perception presents an opportunity for a DX to play a mediating role in ensuring that data flowing through a DX meets standards agreed upon by participating businesses. In addition to ensuring standards, DXs may also play a role in creating accessible data through user-friendly interfaces, so that farmers and other data consumers can easily engage with data:

> "Let me say our goal [in] IT, if you look at infrastructure, is that you have a scalable infrastructure which can grow with the business and is modular built [...] It's in [...] how your interface looks, how a farmer interacts with the interface. If you have 25 connections, a lot of data distributions, a lot of data types. How do you create a user interface which still makes sense?" (DX Interviewee)

Diverse industry needs

It is important that a DX finds common data needs across industry, but also that it does not stretch this beyond what is feasible to avoid becoming too big or being unfit for purpose, and ultimately failing. Ensuring a practical DX and fit-for-purpose data is key to enabling broad participation. Finding common data needs across industries is an important starting point. Achieving all this requires a delicate balance between the various common and divergent needs of the industry:

> "I think there are linkages across the different chains [...] there are similarities across industries, and we hear very similar things. I think there will be some things that are common, but there's a lot of stuff that's not common. There's no other industry that wants the milking data information that we get. Now vet information on the other hand you may have similar things, for instance between beef and dairy. But I would suspect that your veterinary requirement between dairy and poultry are very different. So, I think there's a risk in trying to squeeze a round peg into a square hole." (DX Interviewee)

"I would be very keen to talk about where the overlaps are and how we work together to make those more efficient. So, for instance I would have thought one thing that all of us would want, would be weather station data. Potentially crop yield information from harvesters etcetera because even some dairy farms have harvesters and so forth. So, I think there's some areas of overlap, but I think a danger of trying to make something too big, is that it just fails because it's just too big." (DX Interviewee)

Many DXs believe that beyond a data exchange platform, what is important is to create the data infrastructure to connect to other data infrastructure. Further, data sharing models must have versatility to allow for self-service in sharing, integrating and reusing data. Without these capabilities the capacity to connect, combine and reuse data may be more difficult and costly to implement. Existing DXs discussed challenges of interoperability and how they have addressed the issue of the versatility of a DX in their own spheres:

"[it's] really important [...] we're not trying to create a data platform. What we're trying to do is to create data infrastructure that allows other data infrastructure to connect to one another [...] You create something that is flexible, and messy by design so that you can accommodate things." (DX Interviewee)

"[...] we built the functionality where anybody can come along, you can add a new dataset to the marketplace, you can ingest that data, you can view it. If it's geospatial data, you can view it on a map yourself. Even I can do it, and I've got no expertise. And you can also permission it. So, you choose if you permission it to somebody in the organisation to make it public. You permission it to another organisation. You can also then choose if you want to sell it. So, we've done – all of that is – it's all self-service, because it was about how do we put that – put that in the hands of the users? But also, free up our developer team's time. It's been a real win." (DX Interviewee)

There are differing opinions in the AgTech sector on the role of a DX in facilitating data sharing. One such difference is the perceived ability of APIs to address data sharing issues. However, the ease of implementation of APIs varies across the AgTech sector and depends on the complexity of the datasets and functionality specific to a particular product offering. Some AgTechs are quite comfortable that APIs and token systems meet their current and near future needs, whereas others find them to be complex and of limited use, particularly as the market develops and systems integrations are increasingly required. The below quotations highlight these divergent needs and perspectives:

"I enter into a discussion with somebody, and they say, yes, we want to consume your data, we spin up an API and we send him a key in 20 minutes, like it's no cost." (AgTech Interviewee)

"To date we've got about 100 integrations and they're all individual – you know, we've written the individual integrations with each bit of equipment. It can be [onerous] to write one of those integrations takes anything from three days to three weeks." (AgTech Interviewee)

It appears that businesses that have less complex data interactions are more comfortable with managing their own data connections, however as the scale of data interactions begin to grow, the difficulty and risks associated with managing APIs also increase. AgTechs with relatively more complex data interactions see a benefit to having a third party such as a DX, whose core business is to manage these complex data interactions.

3.1.2 Data quality

This research found data quality to be an important consideration for the proposed AADX. While AgTechs have not explicitly identified data quality as a concern, data standards have been raised by most AgTechs as an important limitation, particularly by those who operate effectively as data integrators ensuring interoperability. A lack of standardisation may be considered a quality issue. In fact, AgTechs have described the amount of pre-processing required to make data useful for their purposes, which is consistent with data quality issues:

> "What we're doing every day, is normalising—standardising [...] datasets so that they're usable." (AgTech Interviewee)

> "[The] mission is to standardise things so people can break down these silos." (AgTech Interviewee)

When it came to Machine Learning (ML) and Artificial Intelligence (AI) applications, the main challenge faced by AgTechs was the availability of high-quality labelled datasets for algorithmic training purposes:

> "The way we do it is that the data we use for training [...] we either collect it ourselves or train people." (AgTech Interviewee)

Anticipating data quality issues, the survey instrument was designed to measure the quality of data shared based on the FAIR principles. The FAIR principles evaluate the quality of data in four main dimensions, namely: (1) *findability*, which ensures the ability to find data through persistent identifiers that are machine-readable and indexable to assist individuals and artificially intelligent systems; (2) *accessibility*, which ensures that the data and other digitised information are available subject to specified conditions of access; (3) *interoperability*, which ensures the data and other digitised information are interoperable via ontologies and communicated through resource description framework (RDF) or other open-source frameworks; and (4) *reusability*, which addresses the demand for data to be reusable, including enhanced provenance metadata (AgReFed, 2023; Wilkinson et al., 2016; Wong et al., 2019; Wong et al., 2022). Along these lines, survey respondents were asked to rate their current data management practices, including the use of public datasets, based on the FAIR data principles. Below are the results.

Findability of data

The findability of data was measured in terms of ease of use in finding the required data and the quality and utility of metadata. Overall, 53%[9] of the respondents reported they sometimes or only rarely were able to find the data required. Further, 25% indicated that data was rarely well-documented, maintained and up-to-date, and 59% indicated they were only able to find reliable, authentic, and trustworthy data sometimes or rarely (See Figure 16).

53% REPORTED THEY WERE **SOMETIMES OR RARELY** ABLE TO FIND REQUIRED DATA

9 Derived from the average of percentage of the responses to the 9 factors in Figure 16 and Figure 17 corresponding to Sometimes/Rarely.

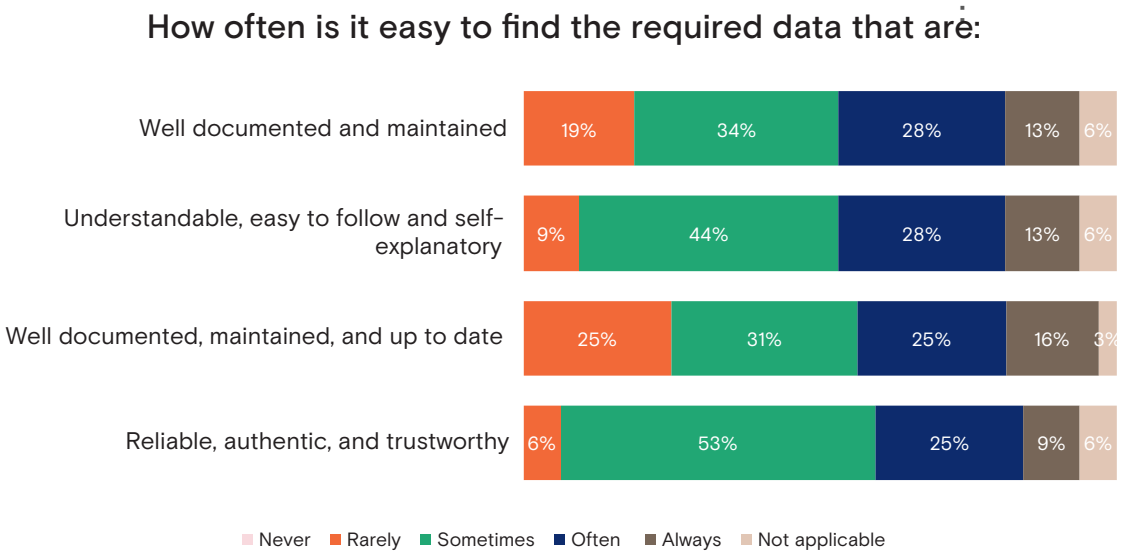


Figure 16 Findability of data

Metadata was explained as details about the data i.e., data title, description, subject, keywords, format, and references. It is interesting to note that 50% of the sample indicated they rarely or never found the metadata useful in their current data sources (See Figure 17). The challenge of findability of data evidenced in the survey exhibits a priority service benefit where the AADX could facilitate the findability of data.

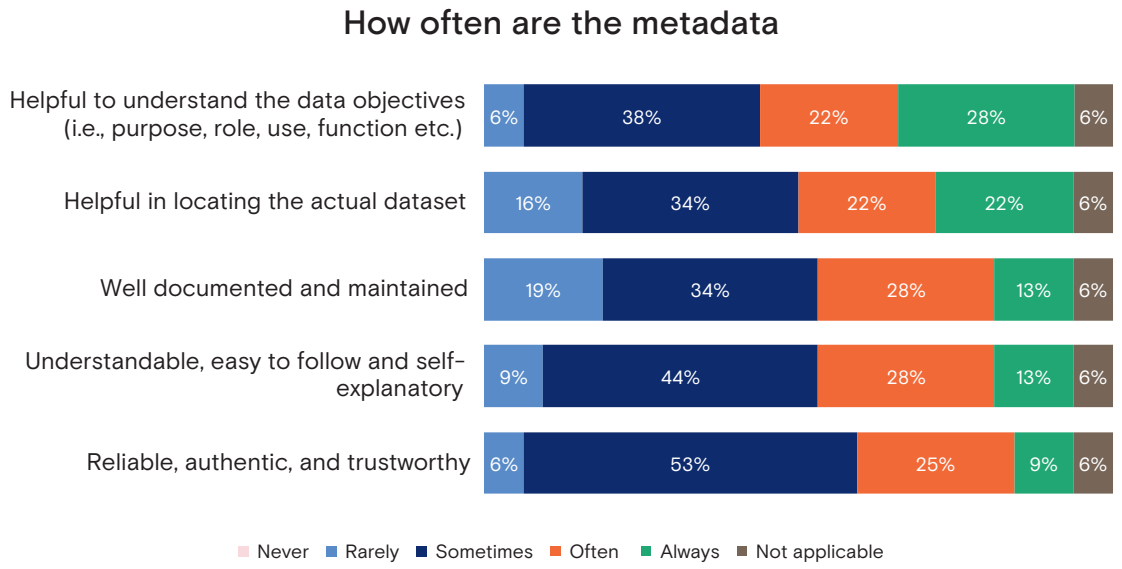


Figure 17 Usefulness of metadata

Accessibility of data

The accessibility of data was examined with respect to the data being accessible, or the ability to find appropriate information if the required data is not available. Overall, 44%[10] of respondents across the two domains shown in Figure 18 and Figure 19 respectively, reported they rarely or only sometimes found the data accessible. 34% suggested data was rarely or only sometimes accessible by following the required authentication and authorisation guidelines (See Figure 18).

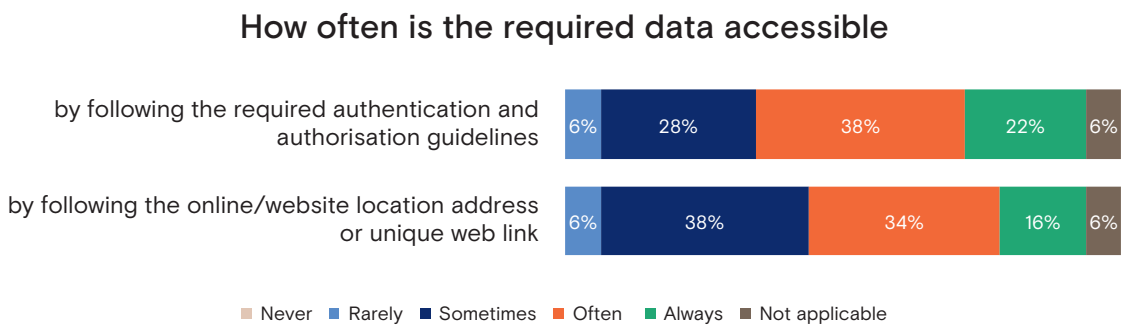


Figure 18 Accessibility of data via data access mechanisms

Where the required data was not available, around 56% of respondents indicated they could frequently find some information related to the data, while 34% could only do so sometimes. 57% indicated they could only rarely or sometimes find details of the creator, owners, or custodian of the data (See Figure 19). These challenges pose impediments to AgTechs being able to access the data they need. Further, that lack of availability of data custodians' details makes correct data attribution and proper permissioning difficult. It therefore seems that a priority benefit of a DX will be in ensuring that data is accessible, and the right attributions are guaranteed.

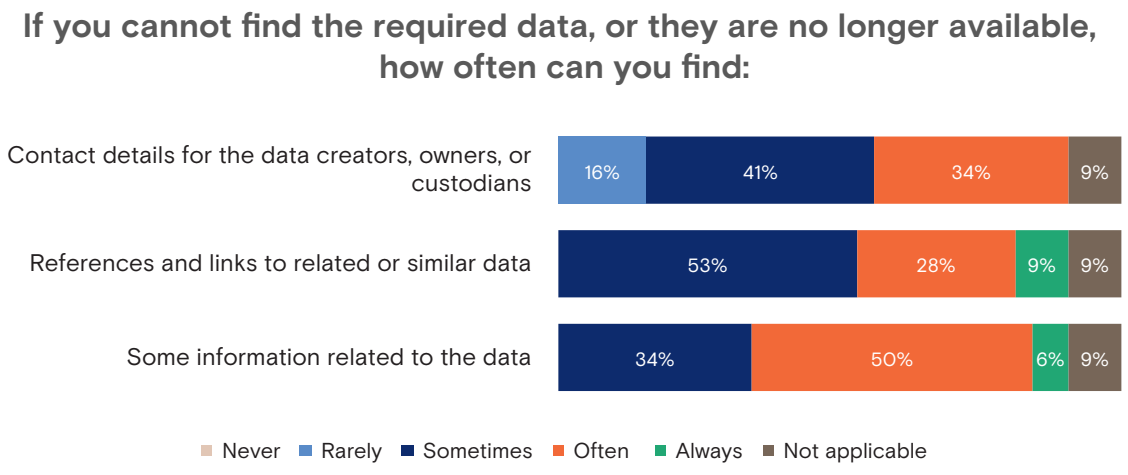


Figure 19 Accessibility of metadata

10 Derived from the average percentages of the responses to the 5 factors in both Figure 18 and Figure 19 corresponding to Sometimes/ Rarely.

Interoperability of data

Regarding data interoperability across the three domains shown in Figure 20, 43%[11] indicated data were frequently (often/always) interoperable, however 25%[12] reported that data were never or rarely interoperable. 43% reported they rarely or only sometimes had data in a file format that was compatible with their technology (See Figure 20). This survey data supports the sentiment expressed by the AgTech interviewees with regards to the effort required in data pre-processing. A DX that facilitates interoperability of data will no doubt be providing a priority service to the AgTech industry.

25% REPORTED DATA WERE NEVER OR RARELY INTEROPERABLE

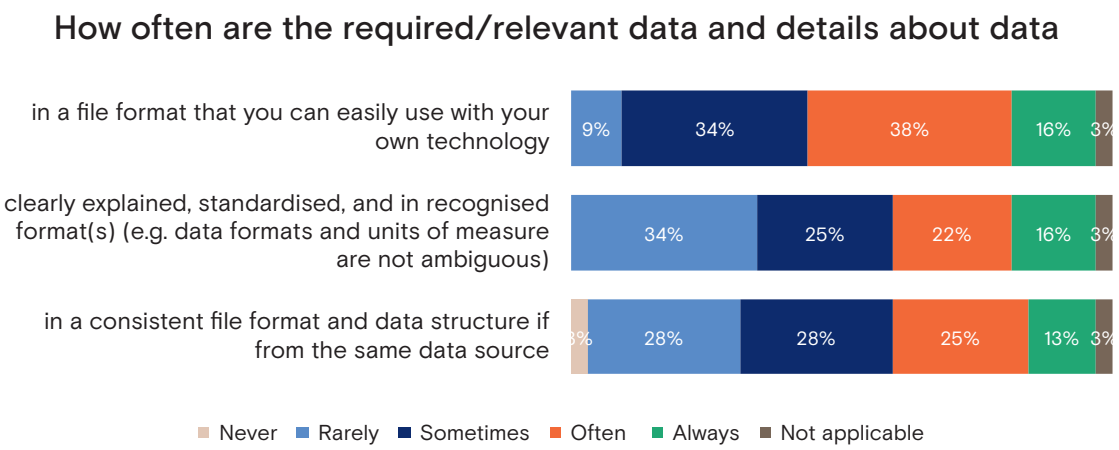


Figure 20 Interoperability of data

Reusability of data

While 48% of respondents indicated they frequently (often/always) found the data reusable, 19% reported never or rarely finding the data reusable. More than half (53%) indicated they rarely or never had information about data licenses, attribution or other requirements (See Figure 21). Clearly, enabling accessing and enhancing understanding of this metadata and the rights associated with data originators would assist in making data reusable. A DX could play a key role in managing data use licenses and enforcing terms of use, which would help to address the issues currently experienced by AgTechs in terms of data reusability.

11 Derived from the average of percentages across Always/Often for the 3 interoperability factors in Figure 20.
12 Derived from the average of percentages across Never/Rarely for the 3 interoperability factors in Figure 20.

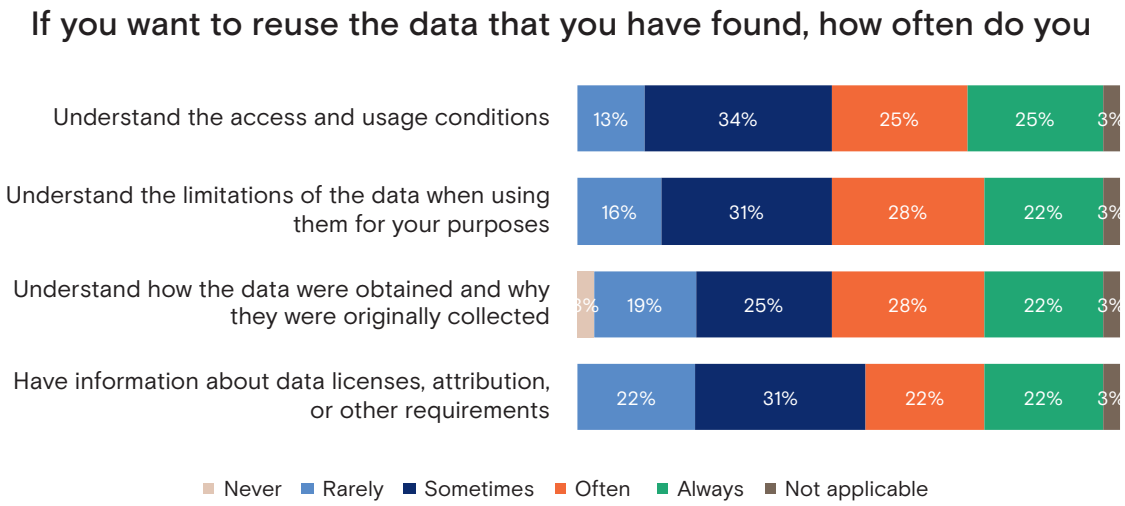


Figure 21 Reusability of data

The above results highlight gaps within the sector that can be closed by ensuring that data is FAIR (Findable, Accessible, Interoperable, and Reusable). As an intermediary, the AADX could assure the quality of data with respect to the FAIR principles.

From the DX viewpoint, there are further important considerations. For example, one interviewee described data quality as dependent on context and intended use:

> "I think, we can't talk about data quality by itself. We have to talk about data quality in conjunction with what it's being used for. So, it needs to be fit for purpose. The data that I want to use for genetic evaluation needs to be QA'd to a very high standard. The data that might be used to inform a decision on farm could possibly be of a much lower quality. We don't talk about data quality, we talk about fit for purpose."

It is conceivable that use cases play a role in the survey responses relating to the FAIR principles i.e., specific use cases or sectors may have satisfactory performance with respect to these principles. Nevertheless, sector-wide quality assurance procedures and standardisation seem necessary to ensure data quality in line with consumer requirements. Poor-quality data remains a concern. As one DX interviewee implied, data handling may not be a core priority for all agricultural supply chain stakeholders:

> "Farmers are great at growing stuff, terrible at typing." (DX Interviewee)

Poor bookkeeping is not the only source of poor-quality data. Deliberate non-reporting and inconsistencies in reporting also undermine the trustworthiness and reliability of data. For example, it may be advantageous to withhold data on weedicide application timing and rates to avoid environmental sanctioning. A successful DX will need to provide assurances on how data is used and governed to alleviate such fears. One DX interviewee insisted that poor-quality data is unfixable and could be the biggest barrier to uptake of a DX:

> "If you start off with really poor-quality data, you can't, well you know, you can't fix it, basically. So, you can't fix the unfixable. You can with machine learning and stuff, but it's really quite difficult." (DX Interviewee)

DXs ought to be concerned about ensuring data quality as DX participants rely on data to be authentic, trustworthy and reliable for strategic decision-making. Strategies and standards need to be put in place to guarantee quality assurance. This represents both a challenge and an opportunity for a DX.

3.1.3 Data-driven innovations

Data is unambiguously seen as providing future opportunities for AgTechs. Indeed, their go to market strategies are all built around data in some form or another. Innovative examples include ingesting data through IoT devices, providing AI and ML tools to support farm decision making, and enabling virtual reality whole of farm data immersion and the simulation of digital twin farming environments. Other more conventional possibilities include benchmarking and agronomic and management decisions:

> "We use [the farmer's data] for benchmarking and (anonymised and aggregated) to look at how [the farmer is performing versus how [their] peers are performing [...] But for now, [the conversation] is around serving the grower to make better agronomic and management decisions [...] Beyond that, there's a whole smorgasbord of opportunities for that data to be used through the supply chain." (AgTech Interviewee)

> "[...] the arguments in favour of unlocking additional efficiencies are kind of incontestable [...] there are and there will continue to be innumerable opportunities for efficiencies presented to any farmer who cares to spend more time looking for correlation, causality." (AgTech Interviewee)

Amid this innovative environment, it is important to not lose sight of the actual context and state of the issues to be addressed by an AADX:

> "Just in the concept we've thought about [the opportunity from aggregated datasets], we haven't actually looked into any practical applications of it [...] Our current customer base is very scattered. It's not like we have a thousand almond farms in the same region where you're going to get some meaningful aggregated data [...] That may come, but at the moment we're all over the place, so there's not really much that you can glean from aggregating that data." (AgTech Interviewee)

The innovation stemming from data requires the data to be made available and for use cases to put the data to work for specific solutions. In the meantime, questions arise as to whether these should come from an intermediary such as a DX, which in turn raises issues of ownership, control, and functionality. These concerns are addressed in the discussions on the democratisation of data under Section 5.1.2.

88% HAVE INTRODUCED **NEW PROCESSES**

One thing seems certain from the survey data, the AgTech industry embraces innovation. Respondents were asked about their practices concerning businesses' innovativeness capabilities in data management and 88% of the sample indicated they have introduced new processes over the last five years (Figure 22).

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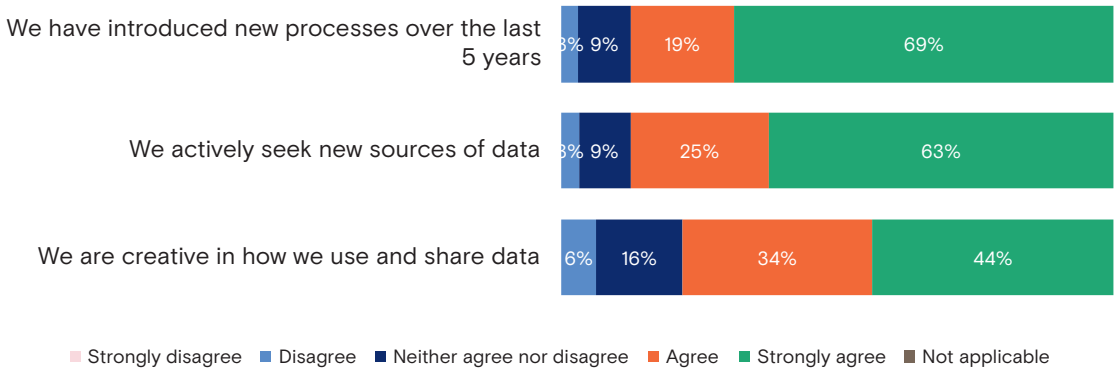


Figure 22 Innovativeness amongst survey respondents

The potential for DXs to accelerate innovativeness seems obvious. This has already been seen in certain sectors of the industry. Farmers increasingly rely on technology to respond to complex operations and to make data-driven decisions to ensure efficiency, lower costs and higher profits. Machine manufacturers rely on connectivity to generate data to make machines more relevant to farmer needs. Along the supply chain, data is needed to demonstrate provenance in line with environmental and ethical requirements and consumer demands:

> "Now smart sensors and devices produce vast amounts of relevant, timely data from different sources to help farmers manage operations and make more informed decisions. These technologies promise higher efficiency, lower expenses, and increased revenue for farmers." (Gleason, 2022)

In principle, businesses can theoretically make better, data-driven decisions that can drive innovation if they participate in safe, responsible, and mutually beneficial data sharing arrangements.

> "[DX] works with other industry partners and within other industries to help develop tools and provide platforms for people to make – what we would say are just data-driven decisions." (DX Interviewee)

3.2 Summary of Key Findings

This section analyses the key findings from the primary investigation with respect to the research objectives. Specifically, this section answers the key research questions: (1) what are the opportunities and challenges facing an Agricultural DX? And (2) what are the key priority service benefits for the Australian AgTech sector?

What are the opportunities and challenges?

- The Australian agricultural sector sees data as a primary driver of innovation. This view is not contested in our research findings by either AgTech or DXs. In fact, 88% of AgTechs have already introduced new processes to manage data in the last five years. There is no doubt that if data is a valued resource, then a DX whose goal is to facilitate the effective sharing of data presents an opportunity to the sector. **A clear opportunity exists for a DX to serve as an enabler to existing AgTechs while incentivising innovation amongst new and existing AgTechs.**

- Data in the agricultural sector is siloed, but there is an industry-wide need to share data. Indeed, our survey reported that 94% of AgTechs share data with one or more external parties, and 50% of AgTechs share data with at least 21 external parties. However, data sharing practices are diverse with different techniques and approaches being used, creating a non-uniform landscape—an opportunity for reform. 41% of AgTechs are not satisfied with how inbound data is integrated and 25% are not satisfied with how outbound data is shared and integrated. **This situation represents a clear opportunity for a DX to mitigate these challenges by facilitating the effective data integrations and interoperability required by the AgTech industry, thereby demonstrating the value of an AADX.**
- Data producers (i.e., farmers) often rely on multiple vendors and systems, and as a result, they may not be aware of what data they have and where this data sits. **An AADX presents an opportunity not only for a farmer to be able to catalogue their data but to also have an oversight of where their datasets are, who has access to them, and for what purposes they can be used. At the same time, an AADX will create an opportunity for AgTechs to know what data farmers may have and how this data can be integrated to their own service offerings to benefit the farmer.**
- There are conflicting views from AgTechs on the importance of a DX in data sharing. While APIs are seen as a suitable approach to tackling the challenge of data sharing, for others they are unsustainable. The former seems to characterise the view of AgTechs with relatively manageable data interactions, while the latter view seems to characterise a view of AgTechs with relatively larger and more diverse data interactions. As the number of data interactions grow, the complexity and risk associated with an AgTech managing their own data connectors increases. This challenge could be catastrophic with the insurgence of cyber security incidents. **In such scenarios, a DX whose core business is to facilitate efficient, secure and permissioned data sharing amongst participating parties, presents an opportunity to the AgTech sector, which may be leveraged to grow the core business of AgTechs.**

What are the priority service benefits?

- Data is used to generate insights by a large portion of the AgTech industry. 97% of AgTechs in this study reported using data to generate insights. **The ability to facilitate data-generated insights is therefore likely a priority service benefit to the industry.**
- Problems caused by inconsistently applied data standards are exacerbated by vast and diverse use case scenarios which may require sector-wide data integration. A one-size-fits-all approach to data standardisation may not be suitable as different businesses interpret standards differently. **A key priority benefit for the sector will be for a DX to play a mediating role to enhance interoperability amongst systems by ensuring consistent application of the relevant standards to relevant use cases, and as agreed upon by the participating businesses.**
- The agricultural industry is very broad with competing and, at times, conflicting interests from stakeholders within the supply chain. This challenge is seen in other DX markets. **A priority service benefit to the industry will be a DX that is self-service, adopting a modular approach, and providing the infrastructure to accommodate differing interests from stakeholders, enabling data consumers to decide how they may interact with data and data sharing.**

- Data quality impacts the insights AgTechs can generate from data, making it an important consideration for the industry. The survey assessed four dimensions of data quality using FAIR principles *(Findability, Accessibility, Interoperability and Reusability)*. It found that:
  - 53% of AgTechs could rarely or only sometimes find reliable, authentic and trustworthy data, and only around 50% found the metadata provided with their data sources useful. **A priority service benefit of a DX will be in its ability to make data findable for the various DX participants.**
  - 44% of AgTechs found data rarely or only sometimes accessible, and 57% could not always find details about the data creators, owners or custodians, making data attribution difficult. **A priority service benefit of a DX will be to ensure that data is accessible to permissioned DX participants and to guarantee the correct data acknowledgements where relevant.**
  - 25% of AgTechs reported data was not interoperable and 43% reported that data was often not in a file format compatible with their technologies. **Thus, a DX that facilitates interoperability of data will no doubt be providing a priority service to the AgTech industry.**
  - 19% of AgTechs reported rarely being able to reuse data and 53% reported a lack of licensing, attribution information, and other required details about data. **A priority service benefit to AgTechs provided by a DX will be in its ability to manage data use licenses and enforce the terms of use of data.**

53%
COULD RARELY OR SOMETIMES FIND
RELIABLE, AUTHENTIC, TRUSTWORTHY DATA

44%
FOUND DATA RARELY OR SOMETIMES
ACCESSIBLE

57%
COULD NOT ALWAYS FIND DETAIL ON
DATA CREATORS, OWNERS OR CUSTODIANS

43%
REPORTED DATA WAS OFTEN
NOT IN A FORMAT COMPATIBLE WITH THEIR TECHNOLOGIES

19%
WERE RARELY ABLE TO
REUSE DATA

- Poor-quality data is attributed by some existing DXs to poor bookkeeping and a lack of willingness or motivation to fully record and share data. **A priority service benefit would be for a DX to provide a complete view and control of data to its custodians, and to facilitate the realisation of the benefit of data sharing to data custodians.**

4 Data Exchange Engagement Barriers and Risks

“A lot of campaign is needed to get both farmers and AgTech vendors on board.” (DX Interviewee)

Globally, the interest in data sharing as a means of wealth creation and in solving crucial common problems is on the rise, underpinned by public-private data exchanges. Yet despite an increasing interest in the future of data economies, the shift from ‘big data’ to ‘shared data’ remains beset by two chronic problems: a lack of trust regarding privacy, security and the appropriate use of data, and a lack of clear, sustainable economics (World Economic Forum, December 15, 2021).

Issues of trust currently prevent vast amounts of data from being shared. This is largely the result of uncertainty regarding the benefits and risks, economic or otherwise, for data holders. Addressing these concerns will be necessary for data to flow through effective data exchanges. This section discusses the barriers and risks to engagement with an AADX by considering the challenges posed by data in relation to economics, trust, security, and rights. Resolving the economics of data exchanges and creating environments of trust are fundamental steps to incentivising data exchange participation.

As discussed, the lack of a standardised means for valuing data is an impediment to data sharing and one of the major challenges facing the consolidation of a data-driven economy (World Economic Forum, December 15, 2021). This can mean that individual data is not seen as valuable and therefore data producers may not benefit monetarily from data sharing. This perception is also seen in the DX interviews where uncertainty around the value of individual data creates the impression in farmers that others are profiting from their data while they are not. A lack of a clear benefit, monetary or otherwise, impedes data sharing by farmers. While individual data may not attract significant monetary value, farmers may benefit from insights gained from that data.

Additionally, DX interviewees described a common concern among farmers that sharing data might result in losses or data being leveraged against them for profit. The benefits of data sharing must be clearly communicated to farmers to encourage interest and overcome mistrust.

A further significant obstacle to data sharing relates to questions of authenticity and reliability. The unique quality of data as an ‘infinitely copyable asset’ poses important questions of authenticity, where knowing whether data has been tampered with or corrupted is key (World Economic Forum, 2022). Establishing an environment of transparency, security and trust is fundamental to enable data sharing and to grow thriving DXs.

Addressing trust in relation to concerns about security and respect for rights can be partially achieved by clear and strong technology and governance standards. Anti-falsification measures, including robust authentication protocols and blockchain-based tracing and verification tools, are crucial technological aspects of creating trusted platforms (World Economic Forum, 2022). Generating trust is also a matter of establishing ethical governance, including but not limited to the creation of enforceable regulations designed to protect the privacy of DX participants and the public (World Economic Forum, 2022). Trust can be built upon a combination of robust security measures and considered governance frameworks.

A further barrier to the development of a data economy is a tendency towards data siloes and data hoarding, whereby exclusive ownership of data is seen as a commercial advantage. This creates a market imbalance between private data ownership on the supply side and the need for data to inform increasingly complex decisions on the demand side (World Economic Forum, December 15, 2021). Data exchanges need to incentivise data sharing for key stakeholders with distinct motives for retaining their data if it they are to enable flourishing digital communities. Incentives will need to combine reduced risks with increased benefits, which can look differently for different supply chain actors and DX participants. Managing relationships with diverse stakeholders will be key to encouraging participation.

The following section of the report will explore some of the barriers to engagement in an AADX, as seen from the perspective of Australian AgTechs and existing DXs. It will also explore some of the risks an AADX might pose to the agricultural supply chain and how these may be mitigated.

4.1 The Research Findings

The research identified four broad areas pertaining to barriers and risks including (1) managing relationships and interests; (2) data governance; (3) risk factors and mitigation; and (4) data reference architectures.

4.1.1 Managing relationships and interests

Exchanging data may involve multiple stakeholders, including government, regulators, DX platforms, data providers, business enterprises, innovators, researchers, and civil society. These relationships are bound by governance. One DX interviewee described this relationship as follows:

> "[...] we're providing a technology, to an orchestrator. This orchestrator is a company [...] so there's a contractual engagement from the solution vendors to an operator. And the operator then will onboard data providers and/or data acquirers [...] the terms of service are defined by the orchestrator, by us [...] And then the data provision they acquire will engage into data transactions through licencing in contracts." (DX Interviewee)

Relationships are ideally built on multistakeholder approaches that promote trust and participation. A consensual approach can be considered to take account of the multiple interests and needs of stakeholders in a way that builds healthy relationships from diversity. As one DX interviewee expressed:

> "We try to really build this network on this diversity [...] because the goal at the end is to find a consensus and if we force everyone to change all the way they work, it's not going to work [...] especially if you have agriculture." (DX Interviewee)

Nonetheless, this relationship-building aspect of DXs is far from simple. The interview data from AgTechs showed some mixed perceptions about an AADX, which speak to the complexity of relationships that need to be managed for data exchanges to occur. Perceptions and sentiments regarding DX platforms can reflect the diverse needs and interests of stakeholders and should be carefully considered.

To establish a baseline of perceptions towards an AADX, our survey measured the sentiment towards a DX. Participants were provided with a description of a data exchange platform based on generic capabilities (see Section 1) and were asked to tell us their thoughts about the idea (both positive and negative). Based on the responses received, 72% appeared to express a positive sentiment towards the idea. With only 13% indicating a negative response. For those with a negative response, the main concerns related to how the platform would be operationalised, believing it would be too complex, or costly to implement in practice (See Figure 23).

72% APPEARED POSITIVE TOWARD THE IDEA OF AN AADX

13% INDICATED NEGATIVE RESPONSE

On the other hand, those who had a positive response believed it would contribute to advancing the industry and creating new opportunities and innovations (n=5) and result in financial benefits (n=3). However, they too, identified implementation concerns (n=9) such as ineffective participation/contribution from some members; the functionality that will enable value creation; the cost of developing such a system; and how the system would be protected and managed.

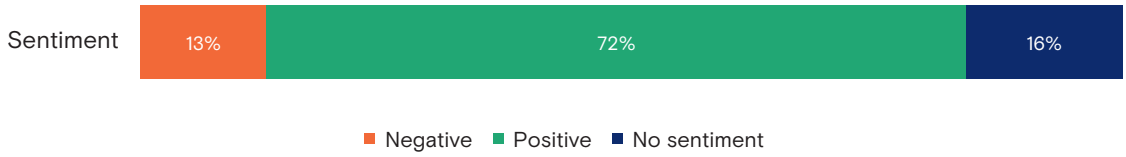


Figure 23 Survey participant sentiment towards AADX

A cross tabulation of the survey respondents' sentiments towards AADX with business size, years in operation and data sharing practices was conducted (see Table 3 in Appendix A4). While overall, most AgTechs were in favour of an AADX, in general, smaller businesses were most in favour. For instance, an overwhelming proportion of businesses with less than 20 employees (83%) supported an AADX initiative, whereas only 50% of large businesses with more than 100 employees were in support of an AADX initiative. Similarly, 82% of businesses who were in operation for less than 10 years supported an AADX, while 60% of businesses who were in operation for 10 years or more were in support of it.

Managing complex competing interests and relationships in establishing an AADX requires careful communication and consistent engagement. This may include understanding the role various stakeholders play in the agricultural supply chain and where value may be derived from the introduction of a DX.

Trust

Trust is a prerequisite to DX participation. It is also a major barrier to data sharing (World Economic Forum, 2022). From our research, a significant factor affecting the trust of businesses in sharing their data or engaging in a DX relates to data abuse. This occurs where data is used for a purpose other than that for which it was collected. This is a legitimate concern that must be strongly guarded against and requires clear governance structures with the involvement of various stakeholders. Possible data abuse of concern includes profiteering from data at the expense of the data producer. This was a common issue raised in the DX interviews, and goes beyond the farmer, as one interviewee illustrates below:

> "[…] if you speak to a farmer, he doesn't want to share all his data […] he'll generally be happy sharing his data with his agronomist [….] They don't want to really share too much with the ag retailer because they think it's going to be used against them. The same goes from the ag retailer up to, if there's a wholesaler involved, well if I tell him what I'm doing, he'll gouge me on price. Same goes to the manufacturer." (DX Interviewee)

A lack of transparency and poorly-defined governance limiting secondary data use needs to be carefully addressed:

> "We just sent the government a list of demands on statutory data. So, Livestock Information Service demand some data, they have a statutory role, but they also have a value-added role. And actually this – this is confusing farmers, and also other organisations involved in sectors […] And the fact that the government organisation will say, well I've got 2 hats okay. I've got the statutory responsibility through governance, provenance, biosecurity, […] But also, we might try and create value-add in data service and products from these data you supplied us […] Farmers then worry, but what does that mean in terms of you just giving my data to some large corporate [to] do something with." (DX Interviewee)

This becomes more problematic in situations where data may be seen as shared with governmental institutions without clear permissioning processes. According to one DX interviewee, historic instances of poor government handling of data have served to perpetuate mistrust:

> "There's also scepticism and suspicion about sharing data. Is my data being shared with government? Because a lot of farmers share data because they have to share data, from a legislation point of view, quality point of view. But there has to be a want. If they see it adds value, they will share more data. But it's a lot of scepticism right now […] in the past government bodies didn't interpret the data correctly and made some conclusions and they were published in newspapers and really damaged trust in the farming community. But some businesses were destroyed by it. And they won't forget." (DX Interviewee)

In addition to gaining trust, enabling data sharing also implies outlining the benefits and incentives to data producers, as discussed above.

Finally, to gain trust, it is vital to limit the AADX role to a neutral one. Some existing DXs propose no additional value-add services, especially where these may be seen as competing with AgTechs. Where the AADX provides a value-add service, there should be clear definitions of their scope. Neutrality could also mean ensuring that the AADX is vendor agnostic. In other words, the DX addresses the interest and technical requirements of stakeholders without any bias.

> "[…] neutrality is almost synonymous with interoperability that we're not creating a proprietary data standard that is used to link data. We're – we're using open data standards so that others can add, and […] develop it. [For neutrality, that is] absolutely critical." (DX interviewee)

"[…] it creates a lot of trust when we say we don't look inside the envelope. This is also the reason why we decided when conversion needs to be done, we do that outside. So, we stay by only transportation." (DX Interviewee)

"We don't touch the data. We don't manipulate the data. We don't combine data. That's all being handled by the third parties that can do that […] Data exchange should be independent of any value-add services, i.e.., DX should not be seen as competing with other tech vendors. This is important for trust. Data exchange should be separated from AgTech – it is a slippery slope to be avoided." (DX Interviewee)

Regardless of the approach, the onus lies on DXs to demonstrate a neutral and transparent offering, while ensuring appropriate levels of consent management.

Stakeholder involvement

"The third area that we do research [on] is probably around the – the more human aspects of data sharing […] what are the psychological barriers to – to engaging [and], how [do] we overcome those? What's the kind of institutional arrangements that we need to put in place in order for – you [to] have confidence as a farmer that when we say that we don't do these nasty things, we're definitely not?" (DX Interviewee)

Human relationships are one of the most significant barriers and/or enablers for DXs. Barriers to data sharing can best be overcome by engaging stakeholders and establishing good governance to safeguard privacy, respect rights and minimise conflicts between stakeholders. Proper governance structures and genuine stakeholder engagement ensure that conflicting interests at different stages of the data value cycle are identified early and mitigated. Ensuring that a potential DX is not viewed as an imposition, but an opportunity requires timely and genuine consultation:

"[…] one of the reasons we set up the way we did, was so that people could see that they had a direct stake in what we were doing […] if people don't see that they've got a stake in it, it lessens their willingness potentially to play the game. And if it's, if it's imposed on them, again it lessens the chance that it'll happen […] I think you need that trusted intermediary who's not in it for their own good, they're in it for the good of the broader industry and particularly the farmers." (DX Interviewee)

This project found resistance among certain sectors of the Australian AgTech community to the idea of an AADX. This seems to emanate from the feeling that there is no demand for such a platform and that this would be a top-down imposition where data sharing needs could otherwise be addressed through APIs. Related, was the idea that standards adherence and data quality would be better assured by the immediate custodians of the data, rather than a centralised third-party DX:

"[A] fundamental of data management is that data should be staying with the data custodian, and so all you are doing […] with a central repository is basically creating a white elephant that has to be continually updated by the data custodians. So why not get it from the point of truth? Why not have an API that we do that says we are getting that data from the point of truth?" (AgTech Interviewee)

> "Once 10-15 years ago you had to define the [standard] and then you had to [...] store that data in a common centralised database to enable people to access it and process it and deliver it. That's just not the case anymore. We have APIs to do that. We have API keys and other things, so while there has to be some level of data definition—well some level of standards—the definitions can be effectively, can be built by those who want to collaborate and share information. So, the concept of a centralised data lake or a centralised repository in today's technology is fundamentally flawed." (AgTech Interviewee)

Larger enterprise-level AgTech corporations tended to take a pragmatic view. One interviewee made the case that the information technology industry has never been monolithic, and that less complex integration requirements may continue to be met individually by companies. However, going into the future there is value in a DX and AgTechs should avoid re-inventing the wheel; rather, the need for a DX should be left to the market to determine. The following excerpt from an AgTech interviewee illustrates that point:

> "You wouldn't want AgTech to build their own cloud, like you wouldn't want them to build their own data standards like you wouldn't want them to build their own connectivity platform. If you're wanting to share data up and down the supply chain that's a product that exists that can be brought off the shelf, whether that's a [particular large IT company] or another provider that can then provide the foundations."

These differing viewpoints illustrate a divergent conceptualisation of an AADX and its role within the stakeholder community. They highlight the value of the broad conceptualisation described earlier in Figure 8, which encompasses DX approaches ranging from the simple use of APIs to move data between machinery and systems on an individual farm, to a public platform with complex analytical services. This approach provides a consensual basis for stakeholder engagement pre-empting potentially conflicting interests and barriers to adoption. Further, the approach provides a basis for considering the topic of institutional structures as a foundational aspect of DXs and their relationship-building architecture. The discussion on stakeholder engagement reminds us of the politically charged nature of DXs in a high-stakes context, and the need for risks to be identified and mitigated from the beginning.

Data control and concentration of power

Depending on the institutional structure adopted, a risk DXs pose to the sector relates to the concentration of data power within a single entity. This can lead to the monopolisation of data and create the possibility for abuse of power or market collapse. As one DX interviewee expressed:

> "You are potentially creating a very high concentration of power [...] in the space [...] if there's a market failure then there's risk of that power being wielded and used in ways which are not necessarily in the best interest of society as a whole [...] there needs to be some form of regulation probably to ensure that market failure [...] doesn't happen."

A further, related risk of data control involves ensuring that the whole of supply chain is secure. Regulation and governance standards serve to reduce the risk of market failure and ought to address all actors in the supply chain:

> "[...] operational risk comes in around things like [...] How do you ensure there is security up and down supply chains for data? Because not everybody has what we have in terms of standards of governance [...] or cyber central's trust compliance etcetera." (DX Interviewee)

Data control should also take account of the ability of farmers and other data producers to determine who can access their data, for what purposes and for how long. To ensure data control, easy-to-use and self-service data consent management and permissioning tools should be available to data producers. Eightwire, a global data exchange based in New Zealand, describes the importance of data control to the agricultural industry:

> "Eightwire's ability to deliver permissions-based sector data exchange allows the farms to create a data vault that pulls data from all of the different technology devices and farm management software and makes it easy to share with regulators and other partners. This gives the farmer control of their data and allows regulators to access the environmental data they need without adding overheads to the farmer. It also gives the farmer insights into where their data is going and how it is used. If companies want to access the data vault, then the farmer can make that call and get a portion of the value from it. It won't be much but at least they will be part of the value chain. At least the farmer is engaged in the process. And they also have the option to say no, with the exception of compliance requirements obviously." (Gleason, 2022)

Traceability can protect that same data from being shared or used beyond what the farmer has consented it be used for. Consent management tools minimise the risk of data abuse and assist farmers to easily control how their data is being used and by whom, and thus makes it more likely that they will share data.

Value proposition

Establishing the value proposition of an Australian Agricultural DX and communicating this clearly to its target audience should be a priority for the AADX. The interview data suggested that it is presently unclear to some AgTechs if a data exchange has an ability to add value to the sector or whether it would add more bureaucracy and another layer of complexity. Most AgTechs who were not amenable to the idea of an AADX did not see any value in, or demand for, a DX. While some AgTechs saw DXs as inevitable to the sector, there was a concern that an AADX could become competitive to other existing AgTechs. This was seen as a barrier to engagement by AgTechs. This reticence is captured below:

> "It's actually about utility and to what extent, if any, a centralised data exchange will actually add value, or it will just add layers of complexity that are not required." (AgTech Interviewee)

> "Show us the demand side. Because at the moment, you're proposing to us a solution for a problem that doesn't exist. Show me somebody [...] who says, I want to buy your data and I want to buy it through a centralised exchange because that's the most efficient way for me to capture it." (AgTech Interviewee)

> "The on-farm piece is definitely a competitive type thing [...] the OzAg Data Exchange shouldn't be getting into a competitive space, it should be [...] working out what its lane is and then [...] grow and thrive around its offering of industry-level [...] processor type data." (AgTech Interviewee)

The inevitability of a DX relates to the overall turn towards data-driven global economies, which can lead to the idea that data is something to be guarded for competitive advantage. However, as one AgTech noted, the idea of guarding data for competitive advantage may no longer have a place in the future of data-driven economies:

> "I think it will come down to a sheer weight of numbers. At the moment, because there's little data out there, you're going to protect what you've got, because that's potentially a commercial advantage. But once you get to a point where the public datasets [are] better than what you can maintain yourself then it'll be a different conversation."

The concerns on the value proposition presented in the interview data were not directly observed in the survey. In the survey, respondents were asked to indicate the benefits they perceived a DX platform would provide. Overall, across the four benefits listed in the survey, 62%[13] of the participants believed a data exchange platform in Australia would be advantageous (Agree/Strongly Agree), whereas 14%[14] did not. Specifically, 75% (Strongly Agree/Agree) indicated such a platform would provide access to better information for decision-making. However, 20% (Strongly Disagree/Disagree) did not believe it would reduce their current costs of production (See Figure 24).

62% AGREED DX WOULD BE ADVANTAGEOUS

14% DID NOT AGREE

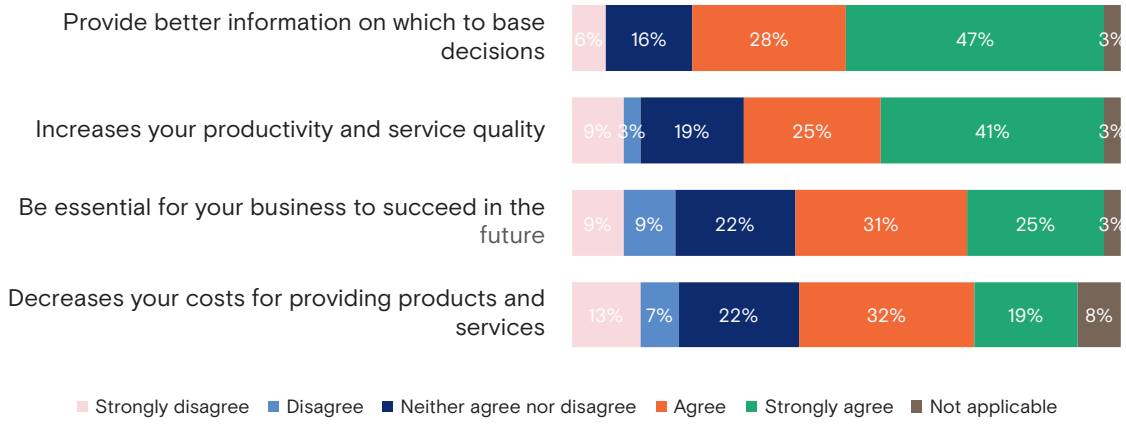


Figure 24 Perceived benefits of a data exchange

While the survey suggests that AgTechs do perceive there to be benefits from a DX, concerns around cost are consistent with the views of AgTechs and DXs alike in the qualitative data. As one interview participant remarked, costs and benefits are contentious because of the various and at times opposing stakeholder interests at play:

> "Barriers are things like cost, because, who pays? […] Technically anything's possible […] but it's a political, it's a business question, those are the stumbling blocks." (DX Interviewee)

Another barrier to engagement in terms of value propositions relates to the uncertain economics of data sharing. The issue of monetisation and the difficulty in defining value on individual pieces of data have created a scenario in which data is clearly generating profits, but not at the point of production. Where mutual benefits are not perceived, little incentive exist for farmers to share their data:

> "The issue, really is around trust, because the farmer has for years been told his data is worth gold, don't give it away for nothing […] you know, there's not a compelling event for them to share their data, unless it's a government mandate that they share, and even then they'll share the minimum they can do to get by, because they believe there's a monetary value, and the challenge is, no one can tell them what it is." (DX Interviewee)

13 Derived from the average percentages of the responses to the 4 factors in Figure 24 corresponding to Strongly Agree/Agree.
14 Derived from the average percentages of the responses to the 4 factors in Figure 24 corresponding to Strongly Disagree/Disagree.

Incentives that seek to ensure all stakeholders benefit from data sharing, and therefore overcome mistrust and encourage participation, can be built into the ethical considerations informing the establishment of data governance frameworks.

4.1.2 Data governance

Data governance is the framework that regulates how data is collected, stored, used, accessed, shared, and deleted (OECD, n.d.). Governance includes technical, policy, regulatory and institutional provisions to ensure data quality, reliability, security, interoperability, usefulness, and respect for the rights of data producers (OECD, n.d.). For example, the EU Data Governance Act regulates DXs so that consumers cannot use data except for the specific purpose it is serving. This section explores data governance relevant to DXs under three main categories viz (1) data regulations; (2) data standards; and (3) data policies.

Data regulation

Data regulations describe a set of rules that regulate how data may be collected, stored, shared, or used, and are enforceable within the applicable jurisdictions. For instance, the European data economy is rapidly being structured around: (1) General Data Protection Regulation (GDPR) to guarantee protections of personal data; (2) Data Governance Act (DGA), which focusses on data intermediation service providers and extends the scope to non-personal data; (3) the Data Act (DA), which focusses on access and use of connected devices' data, fairness in data exchanges, competition and innovation. These regulations extend beyond the EU to any organisation engaging European citizens. Other relevant data regulations include the California Consumer Privacy Act (CCPA) of 2018.

Within the Australian context, an AADX will need to ensure that it is fully compliant with the Australian Privacy Act 1988. The Australian Privacy Act 1988 is underpinned by the Australian Privacy Principles (APPs) which stipulate rules to protect Personally Identifiable Information (PII).

Another Australian regulation that may be relevant to an AADX is the Security of Critical Infrastructure (SOCI) Act 2018. The SOCI Act was designed to manage the national security risks of espionage, sabotage and foreign interference arising from foreign involvement in Australia's critical infrastructure. The Act has three measures to manage national security risks related to critical infrastructure and provides the Government with:

- the visibility of who owns and controls the assets, enabling better targeting of risk assessments;
- the ability to obtain more detailed information from owners and operators of assets in certain circumstances.
- the ability to intervene and issue directions in cases where there are significant national security concerns that cannot be addressed through other means;

DX interviewees corroborated the importance of regulations in ensuring the viability of DXs and spoke to the role of regulations in creating trust, protecting rights, and in affecting the overall playing field:

> "[...] regulations are being developed with the goal of creating and accelerating trust. Because if you don't have trust between the participants within a market data exchange, they will not exchange any data [...] the regulator is defining some requirements so that data can be exchanged more safely, securely, so that there's trust in the participants, in the exchange." (DX interviewee)

"So, regulation will help by giving frameworks that take care of every stakeholder including the small farmers [...] Data Act is about building fairness in a location of value across the various actors of the data economy [...] the regulation will for example, make it mandatory that [...] those who are providing data [...] have a right to, to ask for access to that data. And I will say the manufacturer of the device will have to make it available under certain conditions." (DX Interviewee)

"Including interactions, contacts, licencing, everything that happened [...] So again, the regulation doesn't say how far you have to go, but it's one of the elements of trust creation." (DX interviewee)

Data standards

Data standards refer to the technological specifications for the management of data across systems. They involve the systematisation of data to achieve uniformity across data that is collected, processed, and shared to ensure their proper flow and use; they also improve data quality and allow for its reuse (Satori, n.d.). Data standards affect access and data formats, enhance data security, and prevent improper use by enforcing predefined means to data access (Satori, n.d.). Standards can be open or proprietary, they occur at the level of interoperability, and are often geographically independent. Interoperability and standards are two sides of the same coin:

"When we talk about standards what we mean is there is an interoperability layer, which is over and above the data standards. So – and the role of that interoperability level is to allow standards to talk to one another." (DX Interviewee)

Deciding what standards to adopt is a complex issue that has generated friction in the agricultural industry, preventing agreement on common standards:

"[...] coming together in agreement of standards of approaches across those industry bodies can be quite political at times." (DX Interviewee)

The advantage of open data standards is that they can enable collaborative work to develop those standards, as one participant explained:

"[...] we're not creating a proprietary data standard that is used to link data. We're using open data standards so that others can [...] develop it." (DX Interviewee)

Despite the range of data standards available for adoption, existence alone does not guarantee good data management. It is essential that organisations adopt data standards to protect the rights of data producers and to safeguard against data abuse. As one DX participant revealed:

"I was quite shocked when I landed in this sector five years ago and discovered that no data sharing organisation in this sector had ISO 27001 including us – how dare we pretend to be an organisation that should be trusted with your data, if we haven't shown the basic governance process around information security management." (DX Interviewee)

Below are some relevant standards for consideration in DX creation, they include the Global Standards 1 (GS1) and International Organisation for Standardization (ISO):

Global Standards 1 (GS1)

GS1 is an international standards organisation operational in over 100 countries worldwide. GS1 standards facilitate organisations to identify, capture and share information efficiently by creating a common language that reinforces systems and processes internationally. GS1 supports product traceability and enables digital transformation of products, businesses and industries (GS1, 2018, 2023).

International Organization for Standardization (ISO)

ISO is an independent, non-governmental international organisation with a membership of 167 national standards bodies. ISO brings together experts to share data and develop unpaid, consensus-based, market relevant international standards that support innovation and provide solutions to global challenges (ISO, 2023). The ISO standards address data-related challenges such as data quality, reliability, security, and interoperability.

Data policies

Data policies are courses or principles of action adopted or proposed by an organisation or group thereof to govern their operations in relation to data. Data policies direct all aspects of information asset management throughout the information lifecycle, from data collection and storage to access, use, and security. The relevant Australian agricultural data policies are discussed as follows:

AgReFed Stewardship and Governance

The Agricultural Research Federation (AgReFed) is a federated socio-technical system that focusses primarily on the sharing and reuse of agricultural data, by incorporating metadata, agri-datasets, and other data allied products. The AgReFed platform invites self-governing research partner businesses, government, and private sectors to participate (AgReFed, 2023; ARDC, 2023; CeRDI, 2023). It encourages stakeholder participation: (1) by storing data in line with the FAIR (findable, accessible, interoperable, and reusable) data principles; (2) in association with a federated community and distributed socio-technical architecture; and (3) by collaborating to improve and sustain data FAIRness levels, following data stewardship and governance framework guidelines (AgReFed, 2023; Wilkinson et al., 2016; Wong et al., 2019; Wong et al., 2022).

National Farmers Federation Australia Farm Data Code

The Australian Farm Data Code, developed and adopted by the Australian National Farmers' Federation (NFF) in consultation with industry, aims to promote implementation of digital technologies in the farm sector, by developing a trustworthy environment for agrarians and growers with respect to data use, distribution, and management.

Food Agility CRC data sharing policy and agreement

Food Agility CRC (FACRC) encourages data sharing to propel innovation. FACRC protects the interests of data producers through a data sharing policy that outlines an internal data management structure, providing technical and strategic support to new members (FACRC 2017; 2023).

Five Safes data sharing framework

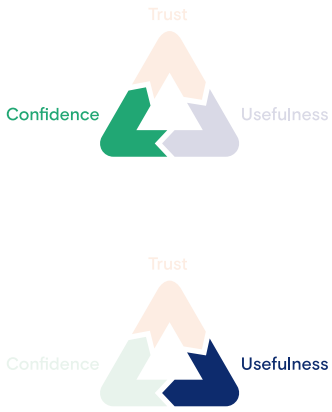
The Five Safes framework identifies five aspects of data sharing that can be vulnerable to risk: safe projects, safe people, safe settings, safe data and safe outputs (Australian Bureau of Statistics, 2021). In recent years, the Five Safes framework has gained popularity in Australia. The framework has been adopted by a number of Australian governments and institutions as their preferred approaches to data management. The list includes: the Australian Bureau of Statistics, the Office of the National Data Commissioner, the Australian Institute of Health and Welfare, the Commonwealth Scientific Industrial and Research Organisation (CSIRO), and various state governments (Culnane et al, 2020). Box et al., (2019), recommend the Five Safes framework be used to guide design of data management and access arrangements for potentially sensitive data. For participants to share their data they must trust that it will be used in ways that are equitable, meet their sharing requirements, and do not disadvantage them.

These policies illustrate the necessity for adopting a clear data policy for the AADX to provide structure and guidance for the actions taken in relation to data and data sharing. This will ensure proper and safe data management and minimise the risks associated with improper data handling and data abuse.

4.1.3 Risk factors and mitigations

In this section, we analyse the potential technical risks of an AADX platform, which can impact the three core requirements of trust, confidence, and usefulness. These requirements have been derived from the primary interview and survey data as well as secondary data from the literature. Handling the technical risks should ensure that the platform is dependable and that DX participants can confidently, reliably, and securely meet their operational needs. The inability of the platform to meet these requirements can lead to costly impacts on the vendors operations, including financial loss, data loss, operational time loss, and health and safety hazards. These can potentially result in several cascading effects, including a lack of interest or total rejection of the platform. The three core requirements expected by DX participants are shown in Figure 25 and discussed below.

Trust relates to issues that may result in diminished trust of DX participants in using the DX platform. For instance, if the capabilities advertised by the platform are misleading, then DX participants cannot perform their functions or will fail in performing their functions. We need to identify these issues to facilitate the elimination of potential risks.



The confidence aspect deals with the use of data and services provided by the platform in the DX participant's analytics and decision-making process. Confidence is directly linked to trust. Potential risks can lead to losing a DX participant's confidence in the data retrieved from the platform. Using the platform may not make sense if they cannot be confident in the analytical results they obtain from the data.

Usefulness deals with how the platform benefits each DX participant. If the platform cannot support any essential business requirement of the DX participant, then the platform is not valuable for them.

Figure 25 Core requirements from the perspective of the DX participant

These three requirements are interrelated such that a lack of trust can result in reduced confidence, leading to a lack of use of data retrieved from the platform. The DX participant-focussed requirements and potential risks are therefore necessary to build trust and confidence, and to ensure that the platform and its services are useful to the DX participant's operations.

The identification of technical risks is primarily informed by the existing standards, principles, and frameworks that can be leveraged to mitigate the risks. The main standardisation bodies we considered are the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC)[15]. These are international standardisation bodies whose standards can be used within any organisation. They also offer certification and compliance guidelines to build trust between an organisation and its partners. We also include other well-known standards such as the National Institute of Standards and Technology (NIST) and open specifications[16] to learn from and adapt. We have categorised the technical risks associated with a DX into five main parts: *data quality assurance, system reliability, system security, interoperability, and user interface and user experience*. While they are all interrelated, the separation ensures that key concerns regarding data consumers, the DX platform, and data producers are clearly outlined. We discuss these parts in detail in the following sections.

Data quality assurance

The data exchange platform will receive and share data from organisations and data sources that were initially siloed and managed by internal standards. Since critical analyses and decisions are expected to be made with the curated data, measuring and improving the data quality is crucial and must be carefully evaluated. As such, the aim of data quality management should be to build confidence in the use of data by DX participants of the DX platform.

15 The list of standards relied upon for risk identification can be found in the Appendix A5.
16 Open specifications refer to all freely available specifications that are designed for specific eco-systems. This includes AgGateway which is specific for agricultural systems.

To evaluate the data quality of the DX platform, we first need to identify a reasonable definition of data quality based on its use cases and requirements. This is necessary for the subsequent identification and treatment of potential risks that may prevent the desired data quality level from being achieved. The result can be used as a data quality assurance framework for evaluating the quality of data from the DX participant's perspective. In addition, since the platform is dynamic with evolving requirements and demands, the framework should be reviewed from time to time. If necessary, it can be extended with additional metrics when more risks are identified.

Data quality dimensions

Data quality is defined from the DX participant's perspective by considering how their workflow aligns with the DX platform and how data quality affects them. Since data quality is complex, a typical approach to defining it in a measurable way is to consider its dimensions within a given context. Based on the DX participant's requirements outlined in project documents[17], we identified data quality dimensions for measuring and evaluating how the DX platform satisfies the user requirements. The dimensions identified are accessibility, timeliness, reliability, interpretability and usability, accuracy and consistency, and completeness. We discuss each further below.

Accessibility

From the DX participant's perspective, the data accessibility dimension of data quality deals with the ease with which data can be retrieved from the DX platform. Accessibility deals with the availability and retrieval process of data. This dimension is critical from the DX participant's perspective, who may need access to relevant data to support their analytics and operations. A risk related to the accessibility of data may include the following:

DQR 1[18]: A DX participant tries to access data from the DX platform but cannot easily retrieve it.

This difficulty can be in the form of slow retrieval, meaningful queries returning invalid data, and design complexities introduced by the DX platform in accessing data, e.g., through the user interface or APIs. Given that the goal of the DX platform is to ensure that information is readily available, this risk must be mitigated. The inability to access data from the platform may lead to the wrong assumption that the required data is unavailable.

Lack of accessibility management can reduce the DX participant's confidence in the DX platform's ability to meet their business requirements. As a result, the platform may not be of value to them and may ultimately be considered a product without significant usefulness.

17 These are the DX project documents that are currently publicly available here
18 DQR stands for Data Quality Risk

Timeliness

The DX platform has a responsibility to provide data that are current for their DX participants since these data may drive time-bound critical decision-making. Timeliness ensures that the curated data on the DX platform are updated with sufficient frequency. From the DX participant's perspective, the timeliness data quality dimension should ensure that data retrieved from the platform are up to date. A potential risk associated with timeliness is given below.

DQR2: The DX participant retrieves data from the DX platform for their operations, but the retrieved data are not current.

The risks associated with this dimension can affect the DX participant's trust and confidence in using data retrieved from the DX platform. Using outdated data in a DX participant's operation can lead to misinformed decision-making, inefficiencies, and financial losses. As a result, DX participants will be less likely to trust data retrieved from the platform and will not base their analytics on it. Their confidence in using the platform will also reduce, ultimately resulting in a lack of interest in the platform entirely.

Reliability

The DX platform has a responsibility to provide reliable and verifiable data from trustworthy sources to DX participants. This dimension is essential because the retrieved data can be used for several data analytics activities and critical decision-making. A risk associated with the reliability of the retrieved data is given below.

DQR3: Data are retrieved from the DX platform for critical decision-making, but the data source cannot be verified.

The DX platform curates data from several data sources and presents it meaningfully to DX participants. However, each data source must be trustworthy to ensure that the curated data are both reliable and verifiable. Most DX participants prefer not to use unreliable data in their critical analytics or operation. However, when this fact is unknown, decisions based on these data can have a catastrophic impact on the DX participant. This impact must be mitigated by ensuring data reliability is appropriately accounted for.

Like the accessibility and timeliness dimensions, reliability can gravely affect a DX participant's trust and confidence in data retrieved from the DX platform. While the availability of data is essential, the reliability of the available data is equally crucial to ensure the usefulness of the data.

Interpretability and usability

The data retrieved from the DX platform should be interpretable and usable within a clearly outlined context. Understanding and interpreting retrieved data is necessary to ensure that it can be used for analysis and decision-making. This dimension is essential because it improves the business value for the DX participant. See the associated interpretability and usability risk for the DX platform DX participant.

DQR4: Data are retrieved from the DX platform for a given context and domain but cannot be interpreted or used.

The inability to interpret retrieved data severely affects the user experience of the DX participant on the platform. DX participants typically expect to understand the context of the data, the domain of the data, and how the data matches their business requirements, operations, and goals. If this cannot be established or investigated from the data, it becomes useless and cannot be incorporated into their processes.

Accuracy and consistency

The data retrieved from the DX platform should be an accurate and verifiable representation of the real-world entity. Data representation in multiple locations in the DX platform should be consistent and maintain the same structure. Maintaining data consistency ensures that each data instance does not change but remains the same and has the same value across locations. This is an essential dimension for the DX platform since the same data can be shared across several DX participants, and the resulting analysis should be consistent. Accuracy and consistency are critical to ensuring data integrity, which should be a paramount requirement of the DX platform. Some examples of accuracy and consistency risks identified are shown below.

DQR5: The accuracy of data retrieved from the DX platform is low or unknown.

DQR6: Data inconsistencies exist when data is stored in multiple locations.

The burden of data verification partly falls on the data producer and should be enforced by the DX platform. In addition, the DX platform can perform additional verification and request for different sources to validate the received data. As such, the DX platform must implement the required strategies for determining inaccuracies and inconsistencies in the curated data. The dissemination of invalid data can negatively affect the analytics and operations of the reliant DX participant.

This dimension is necessary to ensure that DX participants only retrieve and use correct information for analysis and decision-making. Incorrect information can result in diminished trust, leading to a lack of confidence in using data retrieved from the DX platform.

Completeness

This dimension ensures that DX participants have access to the minimum information required to derive meaningfulness from curated data for specific use cases. This requires minimising empty fields and ensuring that data relationships and instances are not missing. As a result, DX participants can perform rich analytics with complete data, consequently driving optimal operations and decision-making. A potential risk relating to completeness is provided below.

DQR7: Data retrieved from the DX platform are incomplete and/or only partially captured.

Completeness improves the DX participant's confidence in using the data retrieved from the platform. Their trust in the platform is also improved or maintained as it becomes valuable to their operations.

Data quality risk analysis

The identified risks must be assessed to determine their likelihood of occurrence and their potential impact on the DX platform and its DX participants. Resolution strategies must then be designed and implemented for each risk, taking into consideration the appropriate contexts. To evaluate the likelihood and severity of each risk, we considered it within the scope of the DX platform and its DX participant's contexts and use cases, as described in the project documents[19]. This process led us to classify the risks, in terms of likelihood and severity, within the risk matrix given in Figure 26. This classification is expected to change during the platform's lifecycle, from its design to deployment and management. This is because the user requirements, contexts, use cases, and other necessary information will be fleshed out and will likely change over time.

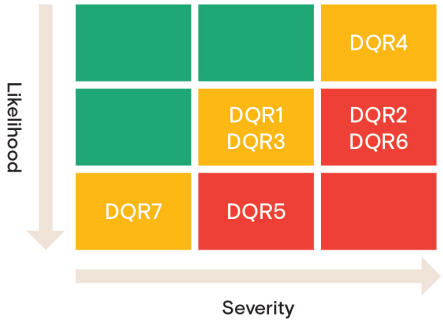


Figure 26 Data quality risk matrix

Since the identified risks are tied to specific data quality dimensions, the relative importance of the dimensions must also be analysed to determine the allocation of resources and efforts to each. While all the dimensions must be considered, a reasonable combination, considering the relative importance of each dimension, is required. This combination should be dynamic and can change as the DX platform evolves and the needs and requirements of the DX participants change.

19 These are the DX project documents that are currently publicly available here

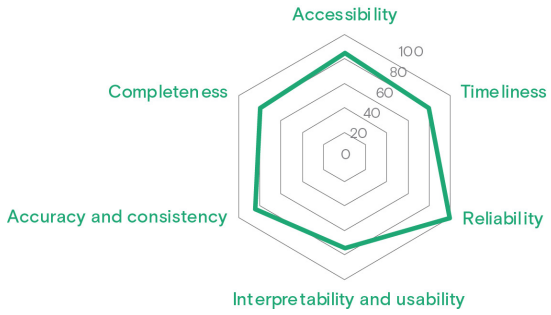


Figure 27 Quality dimension combination snapshot

In Figure 27 we show a possible combination of the identified data quality dimensions based on the current requirements of the project. This graph shows how resources should be allocated to tackle each dimension based on their relative importance. The numbers in the figure range between 0 and 100 indicating the level of importance of the specific dimension. Here, the reliability of the data retrieved from the platform is most important. As discussed above, this graph is expected to change throughout the lifecycle of the DX platform and these numbers are indicative only.

The identified and assessed risks and their respective data quality dimensions must be considered during the design of mitigation strategies. We now move on to potential standards that can be leveraged to handle data quality risks and ensure that the requirements of each data quality dimension are met.

Data quality risk management

There are several standards and proven methods for establishing and managing a data quality assurance framework that the AADX platform can leverage. The identified standards here are a subset of those standards and should form the basis for establishing such a framework or evaluating an existing one.

The first standard we consider is the premier data quality standard, the ISO 8000 series. This series focusses on data quality, data quality assurance, and data quality management. It has several relevant parts, including the following:

- ISO 8000-1:2022 focusses on data quality's foundational structure and requirements, why it is essential, and why it should be measured. It is an essential introductory part of the ISO 8000 series.
- ISO 8000-8:2015 describes the building blocks for the processes and systems of quality management. It provides:
  - The requirements and prerequisites for measuring data and information quality.
  - A structured platform to perform data quality measurement.
  - Requirements for reporting data quality measurements.
- To effectively ensure the integrity and reliability of data, ISO/TS 8000-82:2022 provides standards for capturing requirements in a form that can be processed within the DX platform's information systems and databases. It also outlines how data profiles can be used to formulate effective rules to maintain data integrity and reliability.

- Data profiling is foundational for performing data quality assessment. ISO/TS 8000-81:2021 outlines the procedure for generating data profiles for this purpose. The procedure outlined in the standard includes structure, column, and relationship analysis to determine data elements and dependencies necessary for data profiling.
- The fundamental concepts of data quality management are introduced in ISO/TS 8000-60:2017. These concepts align with the data quality requirements of the DX platform. ISO/TS 8000-60:2017 serves as an initial step in understanding and developing capabilities for data quality management.
- To further develop and concretise capabilities for data quality management, some processes need to be established and implemented. ISO 8000-61:2016 specifies these processes to establish data quality management. The processes are characterised by the purposes, activities, and outcomes necessary for achieving the desired data quality assurance.
- To maintain and sustain data quality assurance, it is essential to establish critical roles and responsibilities for quality management. The methods required for identifying and implementing the functional model of roles and responsibilities are outlined in ISO 8000-150:2022. This document is vital for the long-term management of data quality assurance pertaining to the lifecycle of the DX platform.

  An essential series for quality management is the ISO 9000 family. This series addresses quality management and offers standards and guidelines to assist organisations in improving the quality of their products and services. The goal of the standard is to ensure that organisations consistently meet customer expectations. It tackles several quality management guidelines that can be useful for achieving and maintaining data quality in the DX platform. In addition, it can be applied to the underlying infrastructure, interactions, and applications in the platform. A few standards from the series are discussed below.

- ISO 9001 specifies the requirements for demonstrating and enhancing customer satisfaction. It provides a generic specification that can be easily tailored to the agricultural industries. This standard is typically used with ISO 9002, which provides the guidelines for applying ISO 9001.
- Another necessary standard is the ISO 10005, which can be used as guidelines for establishing, reviewing, accepting, applying, and revising quality plans.
- ISO 10009, which is currently under development, will introduce tools for handling quality issues and improving and maintaining quality in an organisation. It can be used along with quality management systems.

Another data quality standard that can be adopted and used is the ISO/IEC 25012. This standard defines a generic data quality model that can be used to define and evaluate data quality requirements. It provides guidelines for defining data quality processes related to the lifecycle of the data, including data production, acquisition, and integration. The model can also be used to identify potential data quality assurance criteria for improving data quality and evaluating its compliance with requirements. The criteria can be used to manage the data quality dimensions identified in this document and evolve them as the DX platform evolves. ISO/IEC 25012 is part of the ISO/IEC 25000 series, which focusses on software and system quality. Another important standard within this series is the ISO/IEC 25024, which can be leveraged to measure data quality in software systems. Both standards are essential for identifying and measuring data quality elements in the DX platform.

System reliability

We now discuss the requirements for ensuring the system reliability of the AADX platform and its associated external systems. System reliability concerns the assurance given to DX participants of the DX platform regarding the DX participant's operations, analytics, and workloads that may depend either partially or wholly on the platform. This includes the support of the DX participant's goal throughout its entire lifecycle. The DX platform must reliably support and sustain the DX participant's operations to minimise the impact introduced by unreliability. The three main constituents of reliability regarding the DX platform or similar systems are availability, latency, and data quality. We discuss these below.

Availability: the availability of the DX platform to the DX participants can be defined as the fraction of time over a period where the platform is usable. The generally accepted equation for calculating the availability[20] of a system is given below.

$$\text{AVAILABILITY} = \frac{\text{AVAILABLE FOR USE}}{\text{TOTAL TIME PERIOD}}$$

For the DX platform, it is essential to determine the acceptable downtime DX participants are willing to endure with minimal effect on their operations and infrastructure. We say a system is reliable if its *actual availability ≥ desired availability*. For example, an ideal availability for the DX platform is 99.95%, such that the DX platform can only be unavailable for a maximum of 4 hours and 22 minutes in a year. This desired availability can be changed to suit the requirements of the DX platform during its lifecycle.

Latency: this concerns the DX participant's operations on the platform and how latency can affect the user experience and the DX participant's processes. Latency is the amount of time it takes the DX platform to serve its DX participants with requested data. Therefore, minimising the latency on the platform would result in a smoother experience overall for the DX participants. However, latency depends on the platform, DX participants, and other external systems. As such, all these systems should be considered when tackling the potential issues relating to latency.

Data Quality: this deals with the content of the data retrieved from the platform. That is, how good or bad a response is. The data quality requirement of system reliability has been dealt with under the *data quality* dimension section above and should be referred to for more details.

20 Availability can also be calculated based on requests to the system or hardware dependencies.

System Reliability Risk Analysis

We now identify and discuss the possible risks to the reliability of the DX platform. As discussed above, the requirements of the DX platform, in terms of its reliability, are that it should be sufficiently available, have minimal latency, and provide quality responses. The impact of not meeting these requirements will result in the following potential implications for the DX participant:

- **Loss of data:** The DX participant may lose a significant amount of its operational data if the DX platform is unreliable and becomes unavailable, leading to an inability to perform certain functions and activities.
- **Downtime:** This is a potential loss of time due to the DX platform being unavailable. That is, the DX participant's operations that are reliant on the DX platform cannot be performed for some time.
- **Longer running time:** latency will result in unnecessary extra time being spent on activities, potentially leading to an unreliable platform for time-critical processes and decision-making.
- **Increased infrastructure cost:** losses incurred can negatively affect the DX participant's customers or clients, leading to a negative financial impact on the DX participant.

Identifying and treating reliability risks is paramount to ensuring that the system is resilient and reliable. The identified risks are characterised by their likelihood of occurrence and impact on the DX participant. First, we show the developed risk matrix based on the project documents in Figure 28 and then discuss them below.

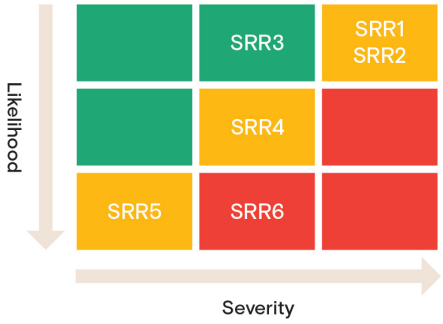


Figure 28 System reliability risk matrix

DX Platform Failure

Failure can be both a hardware and software issue and, if not tackled, can lead to an unacceptable downtime for the DX participants. In addition, disaster events can also lead to severe system failures. Disasters are large-scale undesirable events, such as natural disasters and fires, which can trigger multiple system failures. Below are some potential risks related to failures in the DX platform.

System Reliability Risk (SRR)1[21]: A system failure leads to unacceptable downtown.

SRR2: A system failure leads to the loss of the DX participant's operational data and workload before the failure event.

SRR3: A recovery from a system failure leads to undesired changes to the DX participant's workflow.

Failure cannot be avoided entirely and is bound to occur in any system. It is therefore essential to implement methods to deal with failure. The methods should ensure that DX participants are protected from most failures. At a minimum, the DX platform should have the following features to ensure a desired level of reliability:

- Automatic failure recovery: A protection guarantee for low-level failures should be put in place such that they do not impact DX participants. The protection should ensure that the DX platform is still available for use by the DX participants after low-level failures. In addition, the DX participant's data at the point of failure should be backed up and automatically restored to ensure smooth continuity in their operations.
- Disaster recovery: disaster recovery is necessary to ensure that operations can resume after disaster failures. Since the impact of disasters is more significant than the failure of a single component, disaster recovery may still result in data loss and downtime. The Recovery Time Objective (RTO) and Recovery Point Objective (RPO) must be clearly defined for the DX platform.

Data recovery on the platform may not be holistic and may result in data loss. It must clearly outline the scope of recovery for failures and disasters and the responsibility of a DX participant to ensure the continuity of their operations. This may include backing up data outside the DX platform to ensure sufficient redundancy. Note that the scale and infrastructure of the DX participants can determine if they have the capacity and technical capability to create redundancies. The responsibility of the DX participant must therefore be outlined based on the infrastructure and expertise the DX participant possesses.

21 SRR stands for System Reliability Risk

Change

This aspect deals with downtimes that may result from changes, possibly from the evolution of the DX platform. Change can be in the form of hardware and system architecture, software, and interface changes, among others. It also deals with the potential lack of flexibility of the DX platform in handling changing DX participant requirements.

SRR4: A change in the DX platform results in incompatibility with a previously compatible workflow or operation of a DX participant, leading to downtime or data loss.

Platform evolutions are bound to occur as requirements are modified, existing features are improved or removed, new features are added, and the underlying infrastructure and architecture are modified, among others. While these changes are expected to occur, their impact on the DX participant should be kept at the minimal level.

Extensive testing should be performed to determine the impact of a change before deployment. Potential issues resulting from changes leading to downtime and data loss should be appropriately dealt with. If not possible, DX participants should be notified to modify their workflow and given ample time and support to do so.

High latency

High latency can adversely affect the DX participant's operations, especially if the operations are time sensitive. Critical time-bound decision-making by DX participants may be delayed since their entire process has been slowed down due to the high latency. The latter can be temporary, typically spikes in the latency for a given period, or permanent. Both latency types are undesirable and should be avoided if possible.

SRR5: A DX participant is unable to perform its functions promptly because of high latency.

SRR6: A DX participant cannot increase workload capacity because of high latency. This affects their ability to scale with the DX platform.

Potential causes of high latency on the DX platform may include infrastructure issues and poor architecture and design choices (including hardware and software). For instance, monolithic architectures may be detrimental to the acceptable latency level. Issues may also originate from unnecessary complexities introduced in the platform's design resulting in slow processing of requests. An increase in latency can also signify the inability of the DX platform to handle current (growing) demand on the platform due to the use of outdated infrastructure that should be replaced or architectures that should be updated. Setting the desired level of acceptable latency can inform design choices aimed at reducing latency.

Latency is not only the responsibility of the DX platform, but the DX participants must also reduce the latency that may originate from their infrastructure. Therefore, it may be beneficial for the platform to support DX participants with tools and expertise to guide them in testing and measuring their local latency and how it may affect their operations on the DX platform. This is paramount to ensuring DX participants understand that reducing latency is a shared responsibility.

System Reliability Risk Management

We now discuss some standards that can be applied to achieve the DX platform's desired level of reliability. Reliability and security (to be addressed in the next section) share common characteristics; therefore, some standards may apply to both. As such, some security- and reliability-focussed standards, such as ISO 27000, are discussed under security.

An important aspect of reliability management is identifying, assessing, and managing risks in a structured and concise manner. The ISO 31000 series equips organisations to manage risk efficiently with a clearly defined framework and principles. Based on this framework, this series' IEC/ISO 31010 standard provides guidelines for selecting and applying risk assessment techniques. These risk management standards are generic and can be used by any organisation to ensure long-term success. The DX platform can use these standards to identify possible failure types, disasters, errors, and other factors that can affect the reliable operation of the platform. They can also be used to evaluate the risks from microservices and the external infrastructure that the DX platform depends on. This assessment will determine the reliability of external products and a resolution of products that poses minimal risks to the platform's reliability.

The ISO/IEC 25000 series, discussed briefly in *Data Quality Dimensions Management* section introduces the Software product Quality Requirements and Evaluation (SQuaRE) specification, which provides essential guidelines for designing quality and reliable software and systems. The guidelines include a means to measure and evaluate the quality of a software or system. This is important for assessing the various systems and services that the DX platform depends on and the entire DX platform. The reliability of the platform can be improved if its software infrastructure is dependable. This series' ISO/IEC 25020 standard provides the framework specifically for measuring the quality of software products and systems. The framework evaluates a software product's Quality Measures Elements (QMEs) to determine its reliability and dependability. Typically, ISO/IEC 25021 is used to support the specification of QMEs by providing a format, essential guidelines, and examples for specifying QMEs. The framework supports the measure of quality in the following areas relevant to the DX platform:

1. the measurement of software and system product quality (ISO/IEC 25023),
2. measurement of IT services (ISO/IEC TS 25025),
3. measurement of data quality (ISO/IEC 25024),
4. measurement of quality in use (ISO/IEC 25022).

Another necessary standard that should be considered for system reliability is the ISO/IEC/IEEE 32675. This standard provides guidelines for building reliable and secure systems, including software systems, products, and services. It provides a framework for developing, controlling, and improving the software lifecycle process, from conception to deployment and maintenance. In addition, it provides guidelines for the specification of security and reliability measures to aid in evaluation. The consideration of this standard will be beneficial to the development of the AADX platform. It will ensure that the platform considers the requirement necessary to remain reliable and secure during its entire lifecycle.

System Security

Potential security risks should be identified and mitigated during the platform's design, development, and post-deployment. System security is critical to system reliability and ensures that DX participants can use the DX platform safely and securely. A lack of proper security management on the platform will lead to a (complete) loss of trust and confidence in the system. System security management is identifying, assessing, and mitigating (or eliminating) factors that can cause a loss of assets with unacceptable consequences. An understanding of the assets of the DX platform must be first identified to determine further potential factors that should be mitigated.

In this document, we are mainly concerned with the assets and factors associated with DX participants, noting that these may be indistinguishable from those of the platform itself. The DX participant's assets may include:

- any data, along with its declared intention (e.g., to share, to sell, to share in a sanitised way) that belongs to them;
- any data they should have access to based on their designated access level;
- their activities, workflow, and interactions on the platforms; and
- their security credentials, among others.

The DX platform is responsible for protecting the DX participant's assets, managing their security credentials, handling access management, and protecting the DX participant's privacy. This responsibility is crucial as its impact on the DX participant can be severe, including the loss of data and time, loss of access to data and the platform, operational failures, and financial losses, among others. Therefore, we must identify and treat potential security risks throughout the lifecycle of the DX platform. These identified risks are discussed in the next section.

System Security Risks

System security is closely related to system reliability, and as such, we will omit potential reliability risks already discussed that can also be considered security risks. We show the risk matrix for security risks in Figure 29. This matrix is based on the requirements in the project document from the DX participant's perspective.

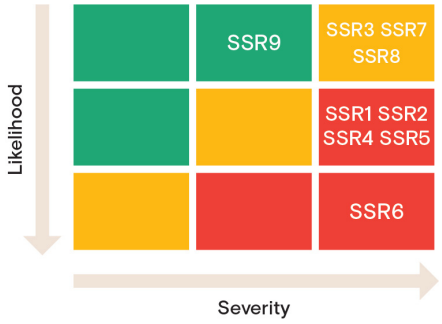


Figure 29 Security risk matrix

The first set of risks is the theft or compromise of a DX participant's security. We capture some of these risks below.

- **System Security Risk (SSR) 1:** Theft of a DX participant's security details leading to an inability to access the platform.
- **SSR 2:** The DX participant's identity and access have been compromised, but the DX participant is not made aware (also possibly unknown to the platform).

  Theft of the DX participant's assets, whether they have access to the platform or not, is a severe security issue. Measures must be implemented to prevent malicious access to the DX participant's assets, including their data. The following risks focus on the loss of assets.

- **SSR 3:** Loss of DX participant's data on the DX platform due to theft or fault.
- **SSR 4:** DX participant's interactions and workflow on the platform are maliciously monitored and exploited.
- **SSR 5:** DX participant's operations are disrupted due to malicious attacks on the DX platform.

Achieving system security is a shared responsibility involving both the platform and the DX participants using the platform. The DX participants are partly responsible for protecting their assets, credentials, and access to the platform. The DX participants must ensure sufficient security protection on the computing systems used to access the platform to ensure that attackers cannot steal their credentials. They must also carefully manage the personnel that have access to the platform to minimise the likelihood of breaches. These responsibilities must be clearly outlined for the DX platform participants. The platform must ensure that theft of credentials on the platform is not possible. They should be committed to identifying and blocking malicious attackers with stolen credentials based on their pattern of behaviour.

The DX platform has a plethora of potential security risks that can affect its advertised capabilities. These risks may relate to infrastructure (hardware, storage, software, network, databases) damage and failures resulting from the critical dependency of the DX platform on external services. These risks may cause unintended behaviours, resulting in potentially significant damage to DX participants and their assets. While the focus here is not to dive into issues relating to the DX platform's assets, the risks from the resulting failure on the DX participant must be accounted for. These risks are given as follows:

- **SSR 6:** The DX participant cannot access the platform entirely due to the failure of the platform's infrastructure.
- **SSR 7:** Data intended to be private and only shared with selected partners or clients are made public or accessible by unintended parties.
- **SSR 8:** Financial transactions performed on the platform are made public and shared with unintended parties.
- **SSR 9:** The DX participant intends to share anonymised data, but the privacy of the data is compromised.

SSR 6 deals with infrastructure failure, like those captured previously under System Reliability. SSR 7 to SSR 9 focus on malicious attacks on the DX platform (software, databases, etc.) or security issues created by software's unintended (and untested) side effects. SSR 9 is also a privacy issue, which becomes a security issue if not mitigated. The resolution of privacy issues may partly rest on the DX participant, requiring data sanitisation before upload. The platform may also offer a sufficient capability to sanitise data.

System Security Management

We now discuss standards that can be leveraged to support the realisation and management of security on the AADX platform. As discussed in the *Security Assessment* section, reliability and security have similar requirements and standards. Standards such as the 31000 and ISO/IEC/IEEE 32675 have been discussed under system reliability and will therefore not be discussed here.

The ISO/IEC 27000 is a series of premier standards for Information Security Management Systems (ISMS), providing guidelines for establishing, implementing, maintaining, and improving ISMS. It defines the generic requirements for ISMS such that it can be applied to several use cases and organisations. It also outlines the requirements necessary to evaluate the conformity of ISMS. In addition, these standards can be used to establish a common security management vocabulary between the DX platform, product developers, contractors, and other parties involved. Finally, it sets the basis for evaluating the security of the platform and all other parties whose tools, services, or expertise may be required, ensuring that security is not compromised. We discuss some standards in this series below.

- **ISO/IEC 27001** is primarily focussed on providing requirements for the ISMS. The requirements span the ISMS lifecycle within the context of the specific organisation. In addition, it provides guidelines for assessing and treating information security risks, which can be applied during the lifecycle of the DX platform.
- **ISO/IEC 27002:2022** provides guidelines for determining and implementing controls to treat security risks in an ISMS. It is based on the ISO/IEC 27001 and aims to support the realisation of the ISMS.
- **ISO/IEC 27005** provides generic guidelines for security risk management that can be applied to all organisations. It is based on ISO/IEC 27001 and supports the satisfactory implementation of ISMS. The guidelines cover requirement for risk assessment, which includes the identification, analysis, and evaluation of risk, as well as the handling of assessed risks, which includes risk treatment towards elimination, risk acceptance, and risk communication, among others. This standard helps assess security risks that may arise throughout the entire lifecycle of the DX platform and its external systems.
- **ISO/IEC 27701** provides requirements for the management of privacy within the context of an organisation. It provides guidelines for establishing, implementing, maintaining, and improving a Privacy Information Management System (PIMS). Particularly, it focusses on managing Personally Identifiable Information (PII). It is an extension of ISO/IEC 27001 and ISO/IEC 27002 and is based on the privacy framework in ISO/IEC 29100. Establishing a PIMS is paramount to the reliable and secure operations of the DX platform. Adopting a PIMS will reduce the likelihood of privacy violations and, consequently, security breaches.
- **ISO/IEC 27031** deals with the requirements for ensuring preparedness and management of infrastructure during an ITC service and system failure, including systems intrusion, malware infections, and disasters. The guide provides disaster recovery, emergency response and management requirements to ensure business continuity. This will ensure that products, services, and capabilities are provided in a reliable, safe, and secure way with minimum interruptions. This standard is essential for the DX platform to guarantee minimum downtime due to failures and disasters and other impacts such as loss of assets.
- **ISO/IEC 27040** provides requirements for data storage protection during the planning, design, documentation, and implementation phases. It involves the identification, assessment, and treatment of risks pertaining to data storage. This standard is intended to ensure the safe and secure storage, retrieval, and transfer of data, which is paramount to the secure and reliable operation of the DX platform.
- **ISO/IEC AWI TR 27024** is a standard currently under development that may be of interest for the AADX. This standard focusses on using ISO/IEC 27001 standards in governmental and regulatory requirements. It should be monitored to determine its relevance upon release.

The DX platform does not exist in isolation, so its reliability and security may become fragile if external systems are not resilient. Part of mitigating this is to ensure that the supply chain for the platform and other facets of the organisation are sufficiently secure and resilient. This will ensure that the likelihood of failure is minimised internally and externally. The standards we have discussed can provide support for evaluating external security risks. Another standard, the ISO 28000, offers additional guidelines that can be relevant. The ISO 28000 family of standards focusses on security management systems that are particularly relevant to the supply chain. It provides guidelines for risk assessment, implementation of adequate security measures to mitigate risks, and evaluation of compliance. These guidelines will improve the security and resilience of the supply chain by minimising security risks and failures.

These standards can serve as initial considerations for designing security risk management systems for the AADX platform. Several other security risk management standards can be adopted later, most of which are explicitly focussed on specific aspects of the DX platform. Other standards, such as the NIST SP 800-53 and NIST CSF provide guidelines and frameworks for security and privacy management for information systems and organisations.

Interoperability

The AADX platform will need to ensure that various agricultural datasets are curated and easily accessible to DX participants. Interoperability is therefore a critical requirement to ensure the seamless exchange of information. Interoperability is concerned with the ability to share information across systems—noting that the structure and semantics of the data may differ. A DX platform may interact with several systems (mostly proprietary) to curate data and share data in a meaningful format for each system. Interoperability is therefore an important capability of any DX platform.

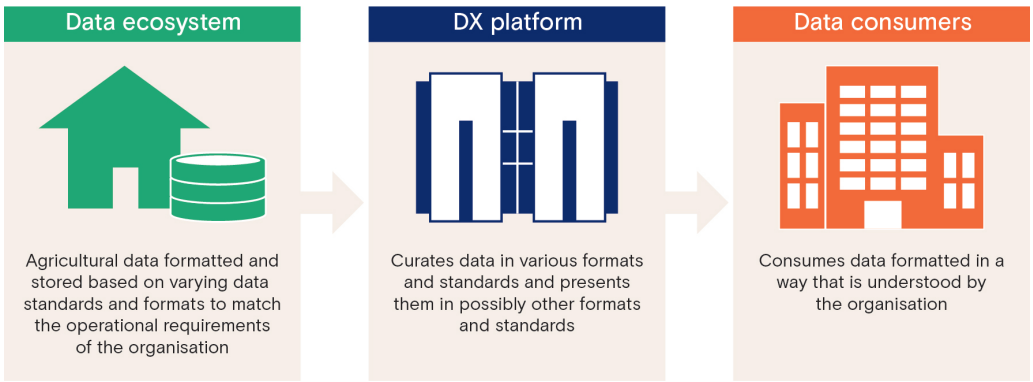


Figure 30 DX platform interactions

In Figure 30 we show an example of the type of interactions that the AADX platform may facilitate. Each data source may be formatted according to external standards or internally agreed upon standards within the organisation. For the data to be meaningful to a consumer, they must receive it in a standard that is understood in their organisation. This leads to a complex many-to-many relationship between producer formats and consumer formats. The DX platform reduces this complexity by serving as the mediator. As such, the AADX platform must be able to semantically and structurally manage interoperability to facilitate the meaningful exchange of information.

Interoperability Risks

We will now discuss the risks associated with interoperability on the DX platform. The likelihood of occurrence of each risk, and their impact on the DX participant is estimated by the Risk Matrix in Figure 31. These risks affect the platform's ability to curate and process data in a meaningful way, as well as its ability to share data with DX participants that are valuable from the perspective of the DX participant. Therefore, a lack of interoperability capability leads to potential risks that affect the platform's usefulness to DX participants and their confidence in using the retrieved data. The identified risks are given below.

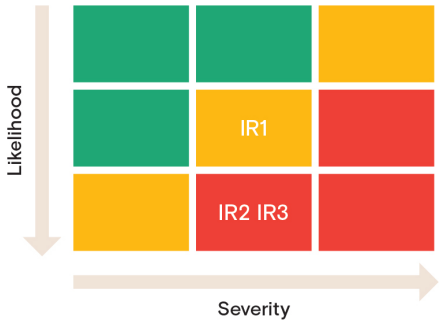


Figure 31 Interoperability risk matrix

Interoperability Risk (IR) 1: The data provider cannot share data because of unsupported standards.

IR 2: The DX participant cannot retrieve data in their preferred standard or structure.

IR 3: The DX participant retrieves data but cannot understand the semantic meaning of the data.

The AADX platform, at minimum, should be capable of providing the following interoperability capabilities to its DX participants:

- The ability to receive, process, and present data based on several agricultural standards in a semantically meaningful way;
- The ability to provide data exchange between various standards and well-known data formats;
- The ability to present meta-data, schemas, and reference data to facilitate the meaningfulness of data from the DX participant's perspective.

The interoperability requirements of the AADX platform must be continuously evaluated during the platform's lifecycle as more standards, data formats, and means of data exchange are introduced. We will consider some foundational standards that can be leveraged for interoperability on the platform.

Interoperability risk management

The AADX platform must support data exchange between the platform and data producers and between the platform and data consumers in a structurally and semantically meaningful way. This requires two essential components: 1) a comprehensive analysis of existing agricultural standards, and 2) a requirement to comprehensively exchange data between standards. This will ensure that data curated to the AADX platform is meaningful and valuable to DX participants. This work will not provide a comprehensive study of interoperability-focussed standards. Still, it will provide some examples of standards that can serve as an initial foundation for interoperability in the AADX platform.

Knowledge of existing agricultural standards can aid in solving potential interoperability issues. An example is ISOBUS (ISO 11783), an agriculture and forestry data exchange standard for serial control and communications data networks for tractors and machinery. Another example is the ISO 11787 standard that provides communication between computers and management computers, which in this case can also be the DX platform for data curation. Understanding the ISO 11787 and ISOBUS exchange protocols is necessary to curate such data. In addition, data schemas and reference data of the various standards would typically be required.

A general-purpose standard that can be adopted in the agricultural context is ISO 20614:2017. This standard describes a Data Exchange Protocol for Interoperability and Preservation (DEPIP). This standard considers three main actors: a data archive, defined as an organisation that intends to preserve information for access; producers of the data; and consumers of the data. The archive serves as an intermediary stage of the data, receiving data and providing access to data consumers. The data exchange platform and related services can be considered the archive. This standard offers guidelines for the following transactions on the archive: transfer, deliver, dispose of, modify, and restore.

We have only discussed a few standards here, but the interoperability landscape is vast, even across the agricultural sector. Further investigations of existing standards and exchange protocols must be conducted to minimise interoperability risks. For instance, it is essential to consider interoperability-focussed technical committees and open specifications and standards for data exchange and interoperability. An interesting technical committee that focusses on interoperability specifications, requirements, and guidelines is the ISO/TC 46/SC 4 Technical Interoperability Committee. This committee is focussed on providing frameworks and specifications to support various aspects of interoperability. An example of an open standards group is AgGateway, which focusses on delivering interoperability capability for several agricultural standards and data formats.

User Interface and User Experience

User experience is crucial to the DX platform. It ensures that the platform is useful to the DX participants and that their experience on the platform is pleasant. The means of interaction on the platform can be through a user interface, APIs, and libraries, among others. Therefore, it is essential to consider how each mode of interaction affects the user. The DX participant's pain points when interacting with the platform must be identified during both low and high-fidelity phases of the development. The identified pain points can then be iteratively used to improve the user's experience on the platform.

The analysis of the risks and standards relating to the user interface and usability is outside the scope of this document; we recommend that it be considered in the future as it can negatively impact the platform's usefulness.

4.1.4 Data Reference Architecture

Reference architecture refers to a document or documents providing recommended structures and integrations of IT products and services to create a particular solution (HPE, 2023). Reference architectures are used by all qualified technology developers to specify required development procedures, minimise obstacles, maintain team focus, prevent cost overruns, and validate final products with customers. For instance, IT4IT and SCOR are information reference architectures for Information Technology functions (Betz & Jahn, 2016) and supply chains (Medini & Bourey, 2012) respectively.

Reference architecture relevant to DXs is exemplified by Gaia-X, a leading European initiative. The Gaia-X architecture enables data and infrastructure ecosystems using elements such as federation service provider, consumers, resource owner, cryptographic signature validation, etc., as explained in the Gaia-X Conceptual Model, the Gaia-X Operating Model, the Federation Services, and the Gaia-X Trust Framework (Gaia-X, 2022). Furthermore, the reference architecture is as an open, transparent, and interoperable ecosystem that presents an appropriate infrastructure in response to the above-mentioned objectives. By enabling sovereign data services, Gaia-X accelerates digitalisation efforts and technological advancements in the agricultural sector. It promotes and develops the digital economy by establishing the next generation of federated data infrastructure.

Coordinated actions on data regulations, standards and policies are powerful levers to: (1) ease and develop collaborations around data, across borders and across industries, and between trusted partners; and (2) ensure the highest level of security and privacy as well as sovereignty to all stakeholders (DAWEX, 2023). It is expected that the Gaia-X initiative will allow representatives from business, science and politics on an international level to shape the next generation of data infrastructure: an open, transparent and secure digital ecosystem, where data and services can be made available, collated and shared in an environment of trust (Gaia-X, 2022).

4.2 Summary of Key Findings

This section analyses the key findings from the research with respect to the research objectives. Specifically, they respond to the research questions: (1) what are the potential barriers to engagement? And (2) what risks are posed by DXs?

What are the potential barriers to engagement?

- While AgTechs in this study generally supported an AADX initiative (72%), smaller AgTechs with fewer than 20 employees and less than 10 years in business operation overwhelmingly supported an AADX initiative. **A potential barrier is that AgTechs with extensive years in the business may have invested in strategies and solutions to handle data sharing. They may themselves have accumulated proprietary data over the years, and the prospect of sharing this data may not be appealing.** If the AADX sits in the wide analytics quadrant of the DX ecosystem, where data may be made publicly available with the potential for some accompanying analytics, then differentiated pricing or value return will become imperative to mitigate participation barriers for AgTechs who may hold the most data. However, if the AADX sits in the *integration services* quadrant, where only a routing or even a data integration service is provided on request, this may mitigate concerns of AgTechs that are presently data custodians.
- **A lack of trust is a significant barrier to engaging with a DX.** Trust can be diminished if there is a lack of transparency and an absence of clear data governance structures to mitigate potential data abuse. Some existing DXs encourage a neutral approach towards handling data within a data exchange. Regardless of the approach taken, **transparency is critical to gain trust in a DX.**

- There is resistance amongst certain sectors of the AgTech community to the idea of an AADX. This resistance appears to stem from the view that there is no need for a top-down imposition of an AADX, which may instead present an added layer of complexity with little to no benefit. The AgTechs with such a view envision an AADX to be a centralised repository that will need to be regularly updated by data providers. On the other hand, larger enterprise-level AgTech corporations believe there is value in an AADX, as it avoids AgTechs re-inventing the wheel. There are multiple stakeholders with varying and sometimes competing interests with the agricultural supply chain. This may influence the perceptions towards a DX. **Overcoming this barrier to engaging with an AADX requires changing the perception of the AADX as a top-down imposition.**
- Changing such a perception requires careful management of complex relationships to ensure that the interests of all stakeholders are met. The involvement of stakeholder groups in the design and development of a DX is important to ensure consistent understanding of the role of a DX and allow conflicting interests to be identified and resolved. **A lack of appropriate multistakeholder engagement can be a serious barrier to the uptake of a DX, as it may alienate some stakeholders.**
- The survey data suggests that 62% of participants see a DX as facilitating better information, increasing productivity and service quality, driving down costs for providing products and services, and as essential for businesses to succeed in the future. **However, the apparent lack of details on the value proposition of an AADX has led** some AgTechs in this study to see the proposal as unnecessary to their operations, while others are concerned that an AADX might become a competitor, rather than an enabler. This creates a barrier for engagement and needs to be addressed. The operational models of an AADX must be communicated and the costs and value return to data producers must be clearly communicated with stakeholders to address their concerns and reduce barriers to engagement.

What risks do DXs pose to AgTechs?

- **The monopolisation of data by a DX is considered a risk that could be posed to AgTechs and the broader sector.** The perception that a DX may be a single repository that holds all data shared creates the sense of a concentration of data power within a single entity—the DX. The degree to which this is possible will depend on the institutional structures adopted by the AADX. Restrictions on the role of the DX in the agricultural sector will need to be clearly articulated and defined through institutional structures and governance frameworks. Technologies, such as blockchain, may also be adopted to map the traceability of how data is manipulated, reused or shared, and thus mitigate these risks.
- Trust, confidence and usefulness are core DX factors that can be impacted by technical risks. Such an impact would adversely affect the uptake of an AADX and ultimately lead to its failure. We identify five main categories of risk namely: (1) data quality, (2) system reliability, (3) system security, (4) interoperability and (5) user interface and user experience.

- Data quality can be defined from the DX participants' perspective by assessing the dimensions of accessibility, timeliness, reliability, interpretability and usability, accuracy and consistency, and completeness. **An absence of strategies to guarantee all of the data quality dimensions poses a significant risk to data quality on the DX, which in turn affects participants' trust and confidence, and usefulness of the AADX.** Standards relevant for mitigating data quality risks include the ISO 8000 and ISO 9000 families.
    - System reliability concerns the assurance given to DX participants of the DX platform regarding the DX participant's operations, analytics, and workloads, which may depend either partially or wholly on the DX. **System reliability risks include platform failure and downtime due to system changes and high latency. System reliability is an important risk factor that can severely impact the confidence and usefulness of the DX.** Relevant standards to mitigate reliability risks include the ISO 31000 series and ISO/IEC 25000 series.
    - System security relates to protecting the system against loss of confidentiality, availability and integrity from adversaries. **Security risks include: the compromise of DX participant's credentials, theft of data assets, loss of confidentiality of data, loss of system availability. System security is an important risk factor that can severely impact the confidence and trust in the DX.** ISO/IEC 27000 series are relevant to ensuring system security.
    - Interoperability is concerned with the ability to share information across systems—noting that the structure and semantics of the data and systems may differ. **Interoperability risks include: data provider being unable to share data on DX due to unsupported standards, inability to retrieve data in preferred standards or structure, and lack of semantic meaning in retrieved data. Lack of interoperability will severely impact usability of the AADX.** Relevant standards include ISOBUS standards and AgGateway open standards.
    - User interface and user experience defines how DX participants will interact with the DX. **There is a risk of the user interface not being easy-to-use or fit for purpose.** This will hamper efforts in encouraging participation. Designing suitable user interfaces requires an understanding of the different user groups and providing relevant interfaces for the relevant user groups, be it through APIs, or graphical user interfaces.
- **Data governance, comprising regulation, standards and policies, as well as data reference architectures, are important tools for mitigating risks posed by DXs.**

5 Characterising the Adoption of Data Exchanges

"[We] would always say we are having companies that are first movers, fast followers and slow followers." (DX interviewee)

The facilitation of adoption of the AADX ought to consider two key factors: ensuring the completeness of the underlying architecture, and convincing stakeholders of its value to them. On this, the World Economic Forum's August 2021 White Paper *Towards a data-driven economy: An enabling framework*, proposes five enablers of data exchanges: availability of datasets in the ecosystem, usability of the datasets, an environment of trust, effective governance and a multistakeholder approach. We have already discussed some of these aspects in the previous section. What remains to consider is how to engage stakeholders and to create an optimal environment for participation—in this case from the perspective of the needs of AgTech—although further research is needed to explore how other key supply chain actors might best participate in this digital ecosystem.

A key element of accelerating adoption is persuasion. According to Diffusion of Innovation Theory (Rogers, 2003), every novel idea carries a certain level of hesitation. This theory purports that, by and large, informative individuals pass through a persuasion stage entailing change on the part of an individual, to build either positive or negative attitudes towards a new concept. This is important because simply knowing about a new idea does not guarantee its adoption. Persuasion involves a certain degree of internal involvement with the innovation on the part of the consumer, which leads to changes in perceptions that affect attitudes (Rogers, 2003). This theory supports the notion that persistent consultation and clear communication with stakeholders is essential to address their concerns and persuade them of the benefits of an AADX.

This section of the report will draw on qualitative interviews and the survey of Australian AgTech providers to identify relevant considerations in designing for maximum benefit within the Australian context. It will also identify some of the key factors to achieve optimal participation in an AADX.

5.1 The Research Findings

The survey asked respondents to indicate what information they would require before deciding to participate in an Australian-based agricultural data exchange platform. For this, participants could nominate three responses that they perceived as being the most important to them. As shown in Figure 32, 'price', and 'governance and operating models' were indicated as being the most important information (both selected by 50% of respondents), followed by 'terms and conditions for participating' (selected by 41% of respondents). The types of data available was the next most selected option.

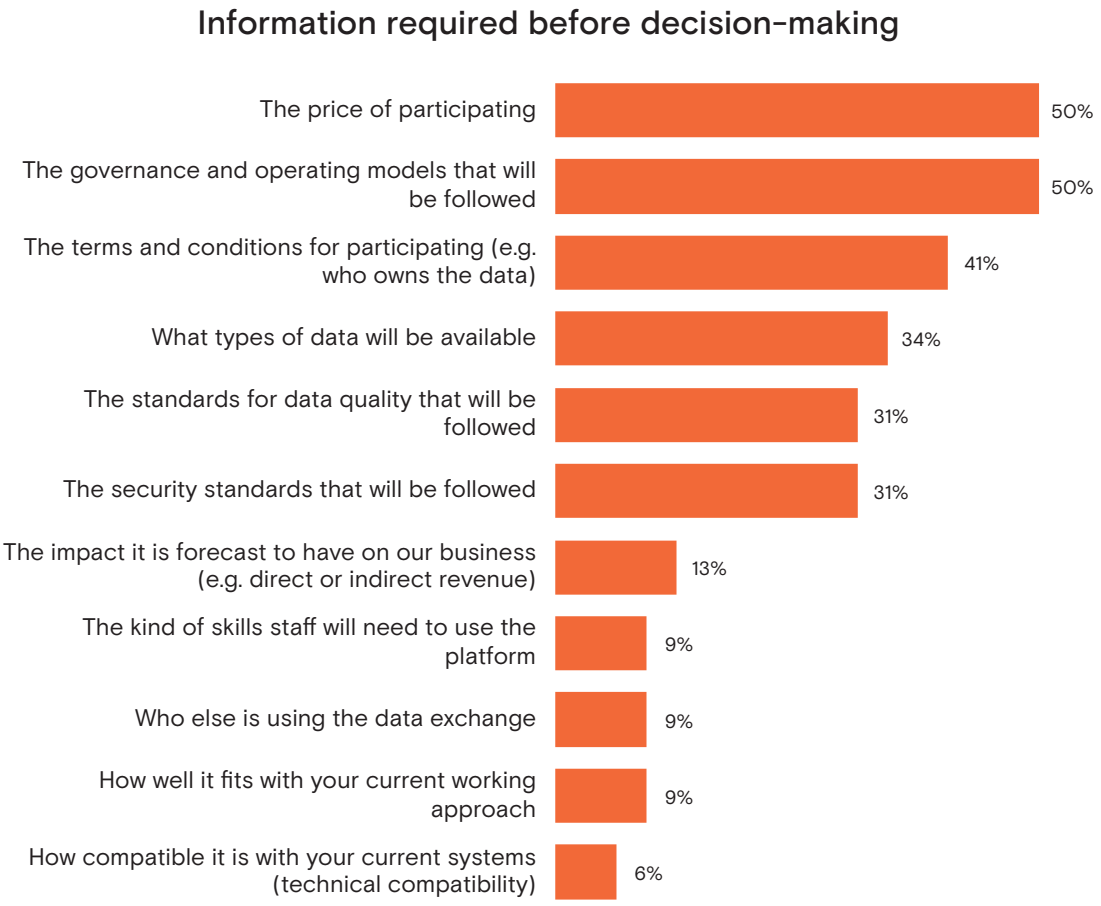


Figure 32 Relevant information required by survey respondents to decide on participating in an AADX

The above results identify some of the key factors that can influence the decision to participate in DXs. Price and payment considerations need to be fully considered in designing an AADX to achieve maximum benefit for the sector. We unpack some of the views on this below. Multistakeholder consultation and clear communication regarding the intended institutional design and associated costs is also key to ensuring the AADX is designed with its users in mind.

In the following sections we synthesise the results from the survey and interview data. The following themes emerged: (1) business models; (2) value propositions; (3) governance; (4) stakeholder engagement; and (5) transparency and traceability.

5.1.1 Business models

Many of the DXs interviewed for this study adopt a non-profit oriented approach. Nonetheless, there are differences in institutional structures that reflect the organisational purpose of each DX. By virtue of their institutional models, DXs can influence the distribution of knowledge and power along the data supply chain. By being mindful of the nature and types of stakeholders, a DX can be designed to uphold the interests of all stakeholders regardless of their size or influence within the market. For instance, one DX decouples membership rights from cost contributions to prevent large corporations from imposing their interests, whilst considering the needs of smaller businesses. Participants described the relationship between their institutional structure and their organisational philosophy:

> "Partners [shareholders/software providers/hardware providers/input companies, all the companies] have one fee per company per year [...] It is important that membership rights to a data exchange are not determined by the turnover or cost contribution made by a partner. This will avoid a powerplay by the bigger AgTech providers." (DX Interviewee)

> "[Our organisation] is a charity, whose mission is to make a more sustainable and profitable industry which supplies to farmers, but also our stakeholders in the genetics and data side." (DX Interviewee)

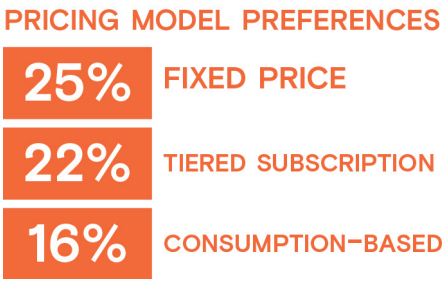
Payment models

Several different payment models were encountered amongst the existing DXs, which also relate to their organisational model and showcase the breadth of possibilities for revenue raising. DXs can generate income by monetising data and/or by offering software services, such as consent management. They can also operate on cost-contribution models to cover their running expenses. Below are some examples.

> "We ask the consumers of data a fee for the distribution of data from A to B. And we have data types in our data catalogue. If they select the data types, there is a fee per data type. It's not a large fee because we are non-profit." (DX Interviewee)

> "Okay, so our business model is a service business model, Software Service [...The deliverable is] to build a roadmap for what is going to be the future data space for agriculture." (DX Interviewee)

Survey respondents were asked to nominate the best payment structure for an Australian-based data exchange. As shown in Figure 33, a quarter (25%) indicated a preference for a fixed pricing approach instead of tiered subscription (22%) or consumption-based payment model (16%). Those who indicated 'other' suggested a combination of the abovementioned payment models, or a bespoke payment model based on use-case scenarios. Only 9% of the respondents indicated that they were not willing to pay to participate.



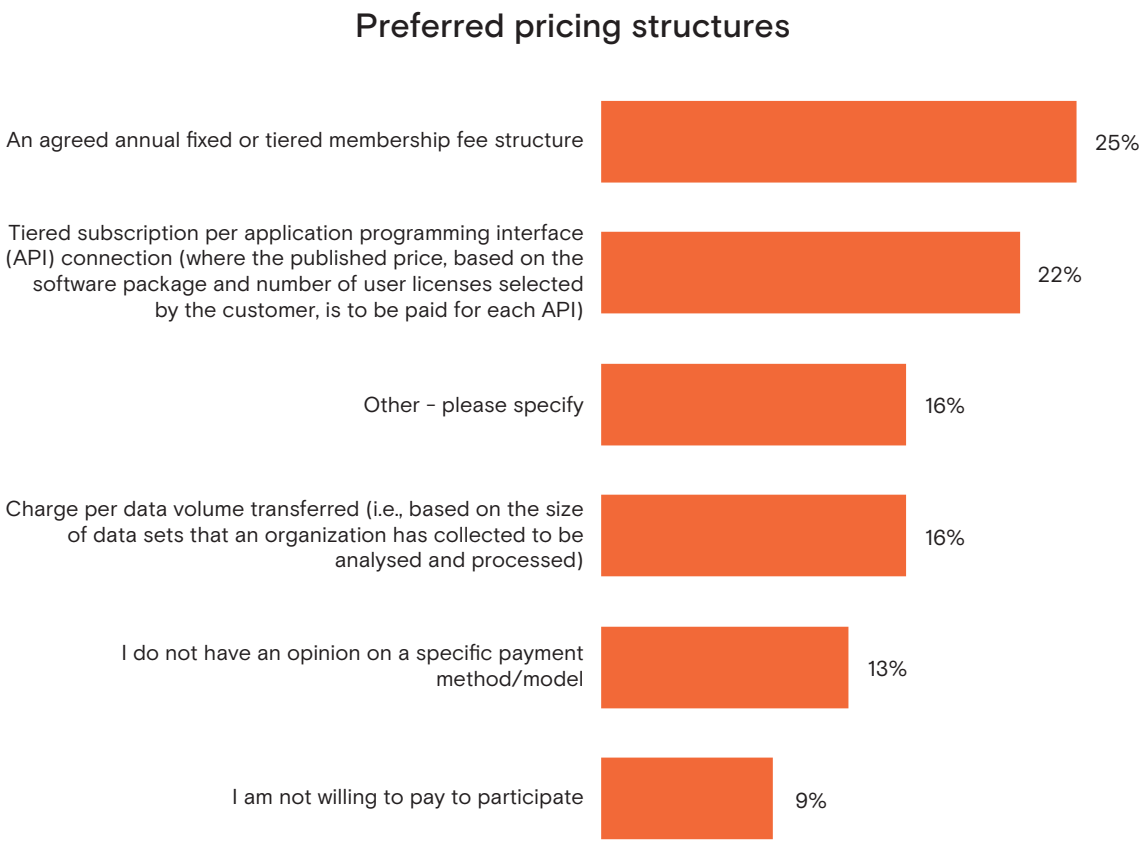


Figure 33 AgTech respondents preferred pricing model

Since the cost of participating was reported as the most relevant piece of information affecting an organisation's decision to participate, careful consideration is warranted on the scope of possibilities and the potential impacts of any chosen model on participation levels.

Institutional preferences

There are mixed views amongst AgTechs in terms of what institutional model the AADX should adopt. One school of thought has the view that the DX should be a commercial initiative:

> "I think [the best institutional environment for a DX] is the private sector." (AgTech Interviewee)

> "[…] public sector will fail. No one will follow the public sector and be attracted to it. So, I think that's out […] And it has to be global." (AgTech Interviewee)

Another school of thought suggests a preference towards a non-commercial institutional approach, such as governmental and quasi-governmental initiative:

> "I think the concept of a co-op has got some logic." (AgTech Interviewee)

> "[…] it has to be run by a government institution right, I don't think it can be a large business […] because [farmers are] all a bit nervous about that side of things, so you've got to have that nice security blanket of governments, government-owned." (AgTech Interviewee)

There are also views that simply recognise that a DX will need to be actively managed and supported:

> "I don't have the answer for [what sort of institution should hold the DX] other than it's going to take a hell a lot of work. It's not going to just sit up there, and – and – and float around. It's going to – and there's going to have to be governance, and privacy [etcetera]." (AgTech Interviewee)

This question was similarly put to survey respondents, who were asked to nominate who should be the best entity to manage the platform. Almost a third (31%) nominating they would prefer if it were run by the agricultural industry. 22% of participants indicated 'other', and this group typically specified that the platform should be run as a hybrid model combining private and public entities (See Figure 34).

ALMOST 1/3 PREFER IT BE RUN BY **AGRICULTURE INDUSTRY**

22% TYPICALLY SPECIFIED A **HYBRID MODEL**

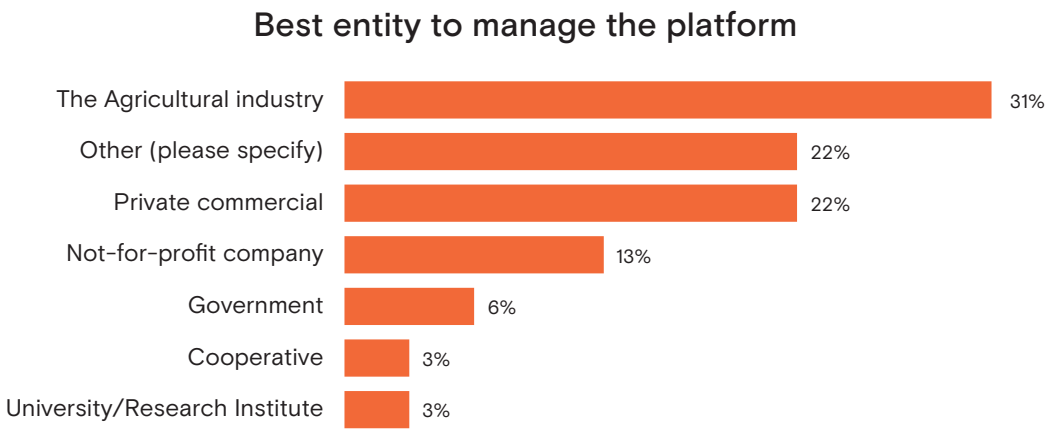


Figure 34 AgTech respondents preferred entity for managing the AADX

Participants were asked to justify the entity that they nominated to manage the platform. These responses are analysed below with respect to their categories.

Agricultural Industry: The leading justification for choosing the agricultural industry related to *maintaining agency over data*; that is, participants felt they would not lose control of their data if it were managed by the agricultural industry. This made up 38% of justifications given. 23% of justifications cited the agricultural industry as being able to *manage costs* due to having a non-profit motive. Other factors that were cited included the *neutrality* of the agricultural industry as well as the ability to provide *longer term stability* for the DX.

Private Commercial: The leading justification for choosing a private commercial entity was the belief in *commercial efficiency,* which made up 63% of justifications given. This underlines the perception that commercial entities may be better at setting-up and managing a commercially viable DX. Other factors cited included *accountability*, potential for *neutrality*, and *longer-term stability*.

Not-For-Profit Company: Not-for-profit company as an entity was seen to be a suitable choice mainly due to the ability to *manage* costs and the potential for *neutrality*.

Government: Government was justified as choice for being able to enforce *regulation*, the potential for *neutrality* and the ability to positively *influence participation*.

Others, such as **University or research institutes** were selected for the potential for *neutrality*, while no reason was given for the selection of a **co-operative**.

Given the diverse justifications for the choices, it is reasonable to infer that the 21% who opted for 'others' citing a hybrid model, expect that hybridity is likely to be more advantageous as it can derive benefits from a combination of the individual entity types. To a great degree, the outcome from these preferences will reflect what functional structure the AADX adopts, and whether it becomes the pipework between entities or a data mart, or both.

Whatever the decision, this divergence of opinions reflects the complex political terrain and diverse interests of actual stakeholders in the agricultural supply chain, albeit limited to the perspective of AgTechs in these cases. Given such diversity of opinions exist within this small sample of a single sector of the industry, it is reasonable to expect that a broader sample of stakeholder opinions could offer a wider and more complex set of ideas. Engaging with these views and managing varying expectations and competing interests is a significant challenge, nonetheless it is key to facilitating adoption.

5.1.2 Value proposition

An echoing theme in this research is that the success of a DX in garnering stakeholder support is intrinsically linked with the value of the proposed DX. It remains crucial to convince stakeholders of the need for an AADX. The success stories of existing DXs in garnering stakeholder support hinge on their ability to clearly define their scope for action and to demonstrate the DX value. The variety of ways in which this has been achieved speak to the organisational strategies at play and are showcased below.

> "[…] at the beginning we thought that we need to standardise data before changing them, we did not succeed […] And I said, okay no, we need first of all we need to establish prototypes and to make the first data exchange platform with a small number of use cases." (DX interviewee)

> "[Our main strategy is] winnings lots of great government contracts that means that we have established ourselves in this space as being trusted by large-scale organisations with sharing public data. That [allows] the platform to be able to grow from there." (DX interviewee)

> "Our mission is to really position what data exchange is and to put it in the value chain […] And that the organisation we're working with have implemented it into their own organisation. And that includes obviously the technology stack […] the intention of today's shareholders is […] to enable their machines to have best connectivity […] to make profit with their machines but not with this company [the DX]." (DX interviewee)

> "In our vision, we want to be the no-brainer in the marketplace. If you want data, you go to [the DX]. Don't do it yourself because it's too expensive, too much legal costs, etc. That's one model. And if data suppliers connect and say, 'but we want to use your consent management tooling' […] they will pay a fee per use… In that way, we cover our costs. I can invest in new technology." (DX interviewee)

These strategies reflect the need to convince data consumers of the value of a DX, be it through offering co-ordinated technologies for simply routing data or through developing modular services, which may also include data accessibility and enrichment through to generating insights as a service.

Core markets

Broadly speaking, the core markets of AgTechs stem from how technology is harnessed to solve farming needs and issues, such as productivity and sustainability. From the perspective of the DXs, the core markets addressed by a data exchange should relate to technology services such as compliance regulations and consent management, rather than data analytics:

> "The security, the compliance regulations, this is really the core of activity [...] so we're not trying to cover the whole value chain of data, we're not providing services in data analytics or data science." (DX interviewee)

DXs should not be seen as competitors to the existing AgTech sector, as this creates a barrier for adoption by AgTechs. To mitigate such perceptions, it is important that the AADX clearly articulates its core market.

Monetisation

Our research found that limiting data exchange benefits to direct monetary compensation creates a narrow view of the value of data, which obscures an understanding of the potential indirect benefits of data. This feeds into the idea that data generates a revenue stream. However, for Australian AgTechs participating in this study, it was unclear how monetisation can be returned to the farmer to any significant degree. This is because the monetary value of individual pieces of data is rated as insignificant and its real value only conceived through aggregation. Indeed, many AgTech participants viewed the practical aspects of monetisation as problematic:

> "[...] this data being the new oil has [...] it rolls off the tongue very easily, but our experience has been that, actually generating cash for it is difficult." (AgTech Interviewee)

> "Just in the concept we've thought about [monetising our datasets], we haven't actually looked into any practical applications of it." (AgTech Interviewee)

This speaks to the problem of the lack of a formal and standardised means for measuring the economic value of data. The opinion generally is that value will be returned to the farmer in some other form, for example through direct cost savings from insights derived from the data, such as identifying more suitable farm inputs or machinery settings, or through indirect cost savings to the farmer through the AgTech vendor.

> "Using [the farmer's] data [...] as long as it's not identifiable to them and it's not breaching any privacy issues, gives me a chance to generate a revenue stream that keeps the cost of my product affordable to them." (AgTech Interviewee)

Rather than income generation, the value returned derives from how a data point from the farm is utilised at different levels of the agricultural supply chain. For example, the worth of the data will differ as you go from the primary producer to wholesaler, retailer, or the bank. The question remains as to how the value is realised, since the value of data also depends on the context and application, the relevance of the data and the actual use it is put to. To simplify the problem and make it possible to put a price on data, it is important to show what uses it can be put to. An approach to this problem might therefore be, to identify the relevant use cases within the data value chain. As one AgTech interviewee mused:

> "The farmer's benefit could be [...] access to markets through being able to validate their carbon footprint [...] I'm a low carbon emitter, the bank because they know, I'm a lower risk. It could come in many forms [...] it could even be monetary [...] but I think that's a low-end opportunity. From the supply chain, clearly it could be the ability to steward my product to the farm and make sure they're using it appropriately, they're not spraying it on a crop at the wrong time or the wrong place. It could be just competitive stewardship and saying my product is better than our competitors. The monetisation [...] there could also be a transactional element, which is where [the AgTech] probably sits and, we say as this data passes through, 'we're going to clip the ticket'." (AgTech interviewee)

What must be remembered in this, is the centrality of relationships to data exchanges, and the need for ethical governance to ensure that value derived for one sector does not come at the expense of another. This can be achieved by guaranteeing some benefits are felt by data producers and that their rights are respected:

> "So, everybody's building a data lake, everybody is still looking at how do I get as much data, how can I ingest as much data as I need so I can build some value for my customers? So that didn't change, but the view changed. So, it's not a defensive data strategy but a more open data strategy. Because in the end, if you give farmer insights on who uses the data and for what purpose the data is being used, and the farmer has the control, if you stop sharing data as a machine supplier, you will lose because the farmer, for the farmer, it's very important that he has, that his needs are acknowledged." (DX interviewee)

Democratisation of Data

It has been noted that centralised DXs run the risk of power imbalances that can lead to monopolies. Data exchanges that centralise data into a single platform and unduly empower certain actors in fact undermine the purpose of a data exchange, which is ultimately to allow the free and open flow of data. For some DX interviewees what makes DXs successful is in fact the democratisation of data:

> "[...] if it would, for instance, store a lot of data, become a database, central database, it's technically not the smartest thing to do, to be honest, to create one point where all the data comes together. But it also creates a shift in power in the system. So, data suppliers would stop sharing data with a central organisation like that because it would have too much power [...] So, you don't want one central point to have so much power because that's not the ultimate goal of data exchange. The ultimate goal of data exchange should be to create an open data system where data sources can be combined in the end by consumers of data on behalf of the farmers." (DX Interviewee)

Along these lines, data ownership and control become key considerations in the establishment of a DX:

> "I guess we have a moral view of the world that [the data] is still [the farmer's] because they're paying us for it." (AgTech Interviewee)

> "You start to go down a sticky path once you start looking at the ownership of data." (AgTech Interviewee)

Regardless of the data ownership viewpoint, AgTechs acknowledge that building trusting partnerships with farmers to ensure that they retain control over their data is critical. All AgTechs were careful to assure farmers of the confidentiality of, and control over, their data. Even where the AgTech has added value to data, they largely recognise that the data originates from the farmer and is the farmer's data to control:

> "The farmer has complete control of his data. He says you can send it to that guy, and to that guy and that guy. That machine can talk to that machine for this day, and they can turn it off". (AgTech Interviewee)

> "[There is a] growing realisation by industries, individuals [and] businesses that companies have abused their powers over data, and people are now increasingly wanting to get a sense that they are in control of that data. And so, we facilitate that, and we also standardise it." (AgTech Interviewee)

5.1.3 Governance

The AADX should aim to balance the free flow of data with the maintenance of trust by demonstrating appropriate and transparent data handling. DX governance should seek a balance between data openness and control, whilst maximising trust, mediating conflicts of interest, and incentivising data reuse (OECD, n.d). One key aspect of effective governance is the establishment of specific roles within the DX to audit DX activities and ensure they are consistent with established institutional policies:

> "I think the other area would be around actually how many organisations truly know what they've got, who owns it, what permissions they've got [...] there wasn't the role – the roles in the organisation, and the skills weren't in the organisation around data stewardship, data governance, data ownership [...] and I see that in so many organisations – commercial, government, and—and the—the industry bodies I suspect are probably worst for that." (DX interviewee)

> "[...] governance is essentially data sharing models. Which governance gives third parties—they could be suppliers of data or consumers of data—enough guarantee that that ecosystem has good governance, is not commercial, won't touch the data, and is only there to enable parties to share data?" (DX interviewee)

5.1.4 Stakeholder engagement

As previously noted, there are diverse stakeholders within the agricultural supply chain that must be engaged in establishing the AADX. Within the scope of this research, industry bodies are seen as one of the key stakeholders that need to be considered. Industry bodies are often seen as trustworthy intermediaries who represent the interests of the respective industries they represent. Ensuring that industry bodies are part of the stakeholder engagement process and affording them the opportunity to represent the interests of their respective industries should inspire trust and facilitate the participation of their members:

> "For members of the industry bodies to participate in a data exchange, it will be ideally through the industry body [...] because I think you need that trusted intermediary who's not in it for their own good, they're in it for the good of the broader industry and particularly the farmers." (DX interviewee)

However, it is also the experience of existing DXs that industry bodies can sometimes have conflicting interests. Being able to mediate these conflicting interests could result in positive engagement for the AADX, for example, regarding agreement on common standards:

> "Coming together in agreement of standards of approaches across those industry bodies can be quite political at times [...] from the farming unions through to the—the grain traders, and—and everybody in between." (DX interviewee)

5.1.5 Transparency and traceability

Transparency and Traceability are key to creating trust and accelerating adoption. Demonstrating that data is authentic and reliable, and that control and consent have been managed and respected, requires proper data accounting and logging practices. Existing technologies can facilitate such processes. Some DXs have advocated for technologies, such as blockchain, to be used to demonstrate what has happened to data, and who has accessed it in its lifetime, for instance, that it has not been manipulated or re-shared without permission. Traceability allows data custodians to better control their data:

> "Transparency is key, and being able to say, if someone says to you in two years' time, well I hear my data's gone to so-so, you can say, well how—here, come and have a look. And again, that's why [...] we built the blockchain separate, it's all about having that separate infrastructure, because you need that trust." (DX interviewee)

> "[...] we had exactly like DHL, right, tracking end points. Any time we touched the data, completely separate to the physical data we store [...] Every time it picks up a message, every time we touched it, we'd generate an event, so anyone could look and say, well what have you done to my data? And you can show them—end to end." (DX interviewee)

5.2 Summary of Key Findings

This section analyses the key findings from the research with respect to the research objectives. Specifically, it aligns with the key research questions: (1) how do we design for maximum benefit and participation opportunities? And (2) what are the models of optimal participation for the AgTech sector?

How do we design for maximum benefit and participation opportunities?

- The business and institutional models can determine to a large extent the nature of the distribution of knowledge and power along the data supply chain, and this can affect the participation of stakeholders along the agricultural supply chain. **The democratisation of data that focusses on its free flow will maximise benefits and create greater opportunities to participate for a wider range of stakeholders, ultimately strengthening the DX.**
- Industry bodies often serve as trusted intermediaries to the industries they represent. Their presence will likely encourage a wider range of participation from the industry and can maximise benefits by taking account of the whole of supply chain. **Early engagement with industry bodies can assist in mediating any conflicting interests that arise in the process, whether technological or political.**

What are the models of optimal participation for the AgTech sector?

- AgTechs in this study ranked the following factors in order of importance to them when deciding to participate in a DX: price (50%), governance and operating models (50%), terms and conditions for participation (41%), types of available data (34%), data quality standards (31%), and security standards (31%) These factors require careful attention to enhance optimal participation rates and are further characterised in this study[22].
- Different payment models have been adopted by existing DXs. These range from fixed fee models to consumption-based payment models. Among the Australian AgTechs surveyed, the three leading preferred payment options were: a fixed pricing model (25%); a tiered subscription-based model (22%); and a consumption-based model (16%). **An Australian DX would have to carefully consider these preferences to ensure optimal participation. Further consultation is recommended to appeal to the widest possible spectrum of potential users, to maximise participation.**

22 Percentages in bracket represent the proportion of survey respondents who selected the factor as important.

- There are diverse views on what type of entity should manage an Australian DX. The survey data suggests the **three leading entities preferred to manage the DX would be agricultural industry (31%); a private commercial entity (22%); and hybrid model of a partnership between private and public entities (22%)**. The considerations made by AgTechs in their choices include:
  - the perceived ability of the entity to enable data providers to maintain agency over data;
  - the perceived ability of the entity to manage costs;
  - the perceived neutrality of the entity;
  - the perceived ability of the entity to provide longer term stability of the AADX;
  - the perceived accountability of the entity; and
  - the perceived ability of the entity to positively influence participation in the AADX

Creating optimal conditions for AgTech participation will require a synthesis of the above considerations. This will likely result in a hybrid, public-private partnership to reconcile the divergent underlying ideologies at play.

- A clearly articulated value proposition is central to enhancing participation within the AgTech Sector. Three key dimensions of value proposition identified are:
  - Core markets: **An AADX should exist as a non-competitive entity** whose role and core markets within the agricultural supply chain are clearly defined. Above all, the AADX **should facilitate stakeholders to derive benefits from data**.
  - Monetisation: Benefits of data exchange should be assessed beyond direct monetary value. The **value-add to stakeholders should be clearly identified along the agricultural supply chain to demonstrate its benefit to stakeholders**.
  - Democratisation of data: **An AADX should aim to facilitate the free and open flow of data** rather than existing as a central repository of data, which can create data monopolies that restrict benefits and hinder participation.

The proposed DX should establish itself as a non-competitive entity that seeks to enable the participation of the whole supply chain by promoting the free flow of data and facilitating multistakeholder benefits.

- Effective and transparent institutional governance can help engender trust, which will facilitate participation in the DX by the AgTech community. **The proposed AADX should embed traceability and use available technology, such as blockchain and anti-falsification measures, to ensure transparency of data handling and demonstrate data authenticity and reliability.**

6 The Impact of Data Exchanges

"There's a whole host of challenges that we face across agriculture—looking after our soils, coping with drought, and flood. How we bring data together across supply chains and work with government, I think there's enough big areas to be focussed on." (DX interviewee)

From the perspective of farmers, data is useful in creating greater efficiency, sustainability and productivity. This includes applications in genetics and provenance. Applications also exist that enable farmers to comply with regulatory and environmental requirements, which often earn farmers greater consumer trust. Eightwire describes the importance of data sharing:

> "There are two reasons why data sharing matters to farmers. One is to meet the ever-increasing regulatory requirements. Secondly, sharing and leveraging data is vital if New Zealand agriculture wants to benefit from the potential strategic advantage that comes with a transparent and trustworthy environmental reputation." (Gleason, 2022)

Data can also be used by AgTech vendors to facilitate the sale of machinery and by investors to predict crop shares. This section of the report will explore the impact of a DX to the public through use cases from existing DXs. It also presents some publicly available datasets that may be included in the Australian DX.

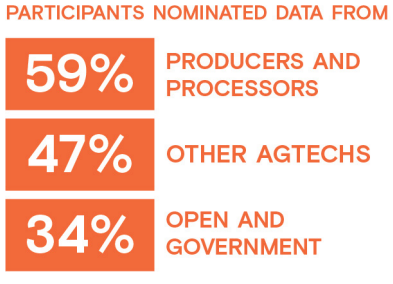
6.1 The Research Findings

This section identifies the various impacts of an AADX on agriculture through an examination of (1) data sources; (2) use case scenarios; and (3) Australian public datasets.

6.1.1 Data sources

Data is created at multiple points across the farm. Agricultural data is produced at farm level through machinery, such as harvesters, tractors and milking machines. Data may also be generated directly by the farmer, agronomist or veterinarian who may physically enter data into a system. Similarly, smart sensors can measure weather phenomena, and geographical, biological and soil characteristics.

This project sought to understand, from the Australian AgTech perspective, which data sources should be prioritised in a DX. As such, survey respondents were asked to provide three responses to what data sources should be integrated into the platform. As shown in Figure 35, 59% of respondents nominated data from producers and processers (i.e., 19 times); 47% nominated data from other AgTechs (i.e., 15 times); 34% nominated open data and government data each (i.e., 11 times each). Other data sources deemed important included domestic and global agricultural market data, regulatory and compliance data, data from service providers, and data from international agricultural supply chains.



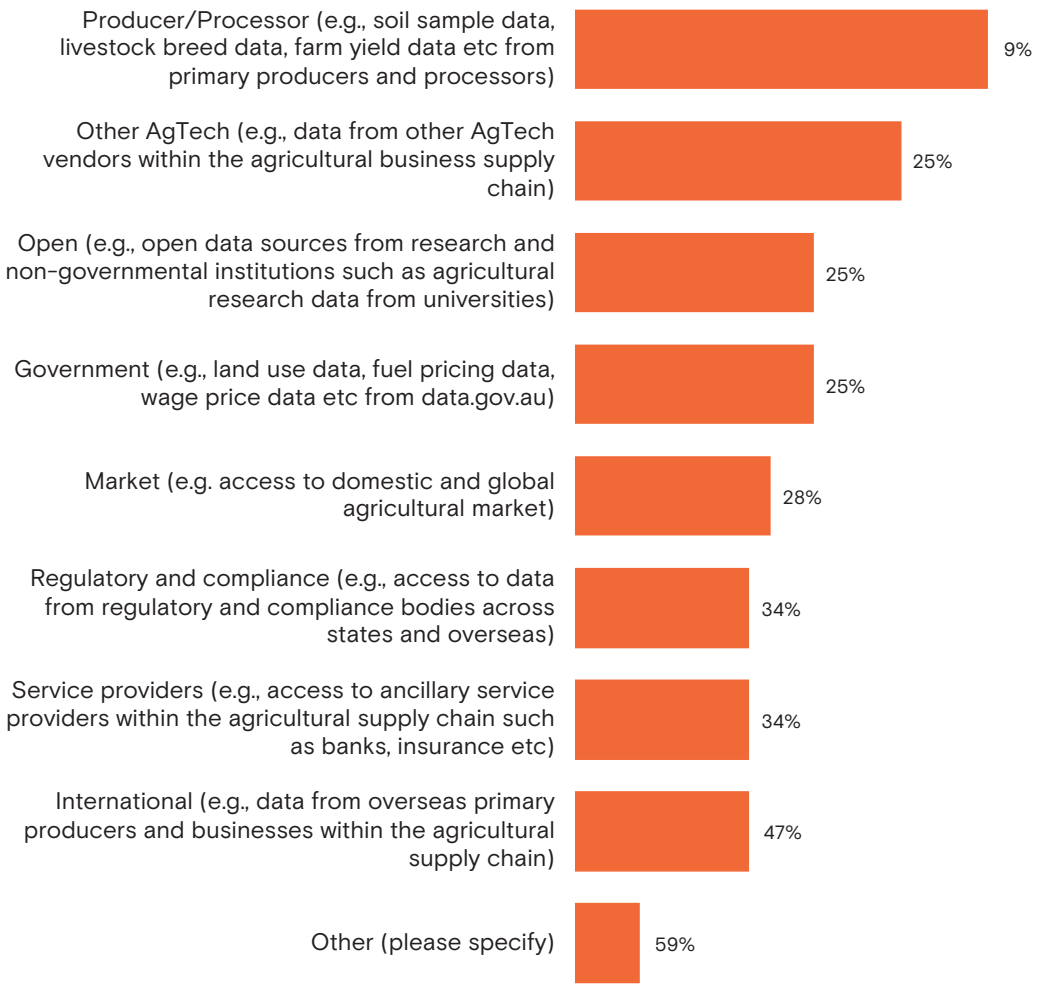


Figure 35 Survey respondents preference for types of data to be made available in the AADX

The above preference for wide-ranging data sources to be included in an AADX suggests the diversity of use cases that may be anticipated by the Australian AgTech community and aligns with interview data from DX participants who considered that a broad, rather than deep dive was needed when exploring use case scenarios. To consider how these might be applied in an Australian context, the following section analyses some use cases from existing DXs around the world.

6.1.2 Use case scenarios

In establishing the utility of an AADX to the agricultural industry, it is important that use cases be based on available data and serve to demonstrate the value of data and of the DX. Existing DXs have expressed the view that it is important that a DX demonstrates how existing data can be used to address common problems, for example, pest and disease control:

> "When you look at the challenges that agriculture faces, you know pest and disease, the loss of chemistry, how to reduce inputs, yield plateau, there's a whole host of challenges that we face across agriculture - looking after our soils, coping with drought, and flood. How we bring data together across supply chains and work with government, as well I think there's enough kind of big areas to be focussed on." (DX Interviewee)

Moreover, DX use cases providing traceability services have been shown to increase productivity and efficiency, minimise waste, permit benchmarking and maintain consumer trust. There are also use cases that support regenerative farming techniques and carbon capture. Further examples abound for data-driven insights in agriculture, which can serve as initial use cases:

> "Weather station information, water, irrigation information that's common across the industries, but you pick one or two of those and say, okay we're going to make it happen on these sorts of data. And try to make it real and show that it's going to work." (DX interviewee)

As the above examples illustrate, when it comes to engaging the AgTech sector and the agricultural industry more broadly, use cases provide important opportunities to demonstrate the tangible value of data to potential users. On this, interviewees from European DXs working with the agricultural sector provided useful insights. One participant suggested that a range of use cases are necessary to create engagement in a DX.

Another interviewee believed that in deciding which use cases to test first, the focus should be on breath rather than depth, to show the end-to-end impact of data sharing along the supply chain. Adding, from a handful of use cases, DXs can then expand to include a data catalogue and a range of additional services, once they have demonstrated their worth and generated interest. Another coincided with this idea, stating, "the trick is to have more than one and less than a dozen," to avoid overreliance on a single use case on the one hand, and biting off more than one can chew on the other.

Use cases that relate to solving common problems, such as climate, soil management and disease control, and those that connect data from one end of the supply chain to the other are of general interest. These use cases are therefore obvious starting points for garnering broad-based interest. One such example is in resolving issues of provenance through traceability, particularly in evidencing ethical or sustainable practices for consumers and compliance purposes. This illustrates the value-add of data exchanges across the length and breadth of the supply chain.

In researching existing use cases, this report identified a number of publicly available agricultural DXs both nationally and internationally. The DXs included: AgriRouter (Germany), Agrimetrics (UK), JoinData (Netherlands), TELUS Agriculture and Consumer Goods (Canada), Proagrica (international), Azure Farm Beats (United States), LetsGrow (Netherlands), AgDataHub (France), AxisTech (Australia), iTrazo Tech (Australia), AgReFed (Australia), and DataGene (Australia). These organisations already operate an impressive array of use cases in a broad spectrum of industries for both specific and generic purposes.

These public DXs offer use cases including research and development in genetic testing and breeding; mitigation of cost and climate pressures; traceability for tomatoes and avocadoes to encourage consumer engagement and ensure quality produce and brand trust; smart technology for greenhouse growers; and machine learning and vision algorithms for proactive decision-making. Others involve the integration of stock movement or the inventorying of data management to enable efficient and transparent financial transactions. The vast array of use cases already in operation illustrates the breadth of possibilities for an AADX to impact AgTech, from livestock to viniculture and seed banks.

Below are a few examples of use cases to illustrate the point.

USE CASE 1: TRACEABILITY

Data that tracks the movement of products up and down the supply chain is valuable for consumers and regulators. This facilitates food certification for consumers to know where their food is from and allows farmers to show provenance. Traceability enables farmers to demonstrate organic, ethical or sustainable farming practices, adding significant value to their products and generating consumer trust:

> *"Generally, people now want to know much more about their food, and so there is much more of an awareness of farming and where food comes from." (DX interviewee)*

> *"That's got to be a selling point for your produce. Better quality data, better information around it, and if you want to check, you know, on the happy life that this animal had on a farm, you can know where this thing came from […] having that ability to share the data, track the data, know what's gone on up and down the supply chain is key." (DX interviewee)*

It also allows for transparent supply chains, which increase the overall trustworthiness of the industry through, for example, food safety and quality assurance, origin verification, certifications and labels, and enabling sustainable sourcing. Traceability also enables new forms of consumer engagement, improved supplier relationships, efficient recalls, and a reduction in fraudulent activities. It is also vital for regulatory compliance.

Current market offerings where traceability is prioritised include those from Proagrica, iTrazo, TELUS, Aerofarms, Ripe.io, and AgDataHub. Some of these are:

1. Agro CloSer enables the tracking and tracing of crop protection products. It was founded by a partnership between Agrodis (crop protection distributors), Nefyto (manufacturers) in the Netherlands and Proagrica (an information and analytics company working in the agricultural industry) to provide complete product and transaction history; intuitive user experience, adaptable to any ERP; real-time visualisation of product movement, location, and transactions and easier communication between businesses, allowing for rapid product recall.
2. iTrazo Tracetech is a platform enabling complete traceability solutions for brand protection and product provenance using unique Active Digital Identity for every item. The platform uses geolocation and trace technology with built-in anti-counterfeiting and product security to track the movements of products.
3. TELUS offers traceability services that allow Persephone and its farming partners to demonstrate the sustainability of their Pollinator Pilsner beer, by scanning a QR code to see how the beer is farmed, brewed, and monitored for safety and quality. Similarly, they offer a software product called Muddy Boots which allows food manufacturers and retail customers to see supply chain actors and evaluate their performance against ethical, corporate social responsibility and sustainability standards. It also allows farmers and agronomists to share crop records and fertiliser and nutrient plans, to manage spending and ensure compliance to audit standards. Seamless sales order integration also reduces back-office order processing costs for retail outlets and reduces uncertainty about lost sales opportunities.

USE CASE 2: OPTIMISATION

The more efficient and productive operations are on the farm, the higher the profits for the farmer and the more they can invest in AgTech. Hence, the value of data in operational and financial management lies in increased productivity, which has a flow on benefit for AgTech. For instance, farmers can access data on breeding values and herd information that will allow them to make more informed business decisions:

> *"I think we've got something like 45 traits at the moment, everything from production through to heat tolerance, feed efficiency, these things. And farmers can choose on both the cow and bull side, the genetics that will deliver them more profit and make them more sustainable." (DX interviewee)*

Farm management practises such as application of fertiliser and weedicide can also be optimised for specific farm conditions, reducing input costs and environmental impacts. Data exchanges can offer multiple possibilities for supply chain organisation with benefits for primary producers through to consumers. Data exchanges also enable collaboration between suppliers to improve communication and ensure quality as well as collaborative planning. They can be used to facilitate price transparency for both producers and consumers, to manage risk including disruptions and for regulatory compliance, as well as for enabling consumer feedback and efficient resource allocation.

Current market offerings where optimisation is prioritised include those from LetsGrow, Agrimetrics, TELUS, Agrivi, IBM, Proagrica, C.H Robinson, Trellis, Blue Circle, FoodLogiQ and Ripe.io. Some of these are:

1. LetsGrow's Data Driven Growing solutions provide data analysis and advice to increase productivity and efficiency in greenhouse operations, including improving production quality and accurately predicting yields.
2. Agrimetrics offer a data marketplace and data governance services as well as data aggregation and analytics that enable farmers to make data-driven decisions to optimise yields and minimise inputs.
3. TELUS offers the Farm Fuel Management System through its Decisive Farming service. The system works on wireless technology that monitors fuel storage tank levels and sends alerts when it is time to refill. The farmer can view levels in real-time via the cloud and can set the threshold for notification. The solution can also be used with liquid fertiliser. The Farm Fuel Management System saves time and effort, reduces downtime, and improves efficiency as well as revealing trends that can help inform cost-cutting measures.
4. Agrivi offers Agrivi360 Farm Insights, an easy-to-use farm management software assisting in efficient crop planning, real-time field insights, easy record-keeping, improved farm profitability, full crop traceability and simplified administration.
5. IBM's Supply Chain Intelligence Suite: Food Trust is a module blockchain based solution that works with all supply chain participants to improve the food ecosystem. Blockchain technology connects Food Trust participants including growers, processors, wholesalers, distributors, manufacturers and retailers to enhance visibility and accountability through permissioned, immutable, shared records of food provenance, transaction data, processing details etc. The Intelligence Suite improves brand trust, compliance, sustainability, safety monitoring, fraud prevention and waste, creating more efficiency across the supply chain.
6. The Proagrica Network is an established digital supply chain platform tailored to the agricultural industry offering automation designed to improve the speed and accuracy of communications and data through a focus on automation, visibility and communication.
7. C.H Robinson offers tools to improve a range of supply chain areas, including sustainability, transportation optimisation, purchase order management, procurement, digital connectivity and demand planning. Offerings include automation, real-time and personalised data visualisations, simulations, recommendations and data insights for increased efficiency and more effective planning.

USE CASE 3: REGULATORY COMPLIANCE

There are several significant applications for regulatory compliance in agricultural data exchanges that can support farmers and stakeholders to satisfy relevant regulations, standards, and policies. These include pesticide usage tracking to prevent misuse of pesticides; facilitating organic certification by maintaining a record of practices and inputs; water resource management in line with relevant rights, permits and regulations; reporting and monitoring for compliance with environmental regulations, including maintaining buffer zones and managing soil erosion; managing food safety and traceability. Data exchanges may also assist in compliance with the relevant requirements of cross-border trade; livestock identification and movement, including health regulation and disease control; labour and workforce compliance including safety protocols and working conditions; and in regulating sustainability practices such as crop rotation and biodiversity protection. Furthermore, data exchanges may facilitate adherence to Genetically Modified Organisms (GMO) and biotechnology regulations to ensure labelling and disclosure requirements are met, and can simplify documentation and reporting requirements as well as certification audits:

> *"Many Kiwi farmers are using cloud-based solutions that are changing how they operate while optimising operations and production. Farm management software is used by farmers to manage farm operations and finances. Regulators require farmers to collect and report on environmental plans that often require the same data." (Gleason, 2022)*

> *"We generate a range of data points. The most obvious one is our genetic breeding values. So, we take the input data from farmers through herd test centres and breed societies and we turn that into a breeding value, which then goes back to farmers. So, in that sense we're a data provider. We also take for instance herd test information and turn it into other reporting things that go back to farmers as well." (DX interviewee)*

Current market offerings where regulatory compliance is prioritised include IBM, Agworld, Croptracker and Ceres Imaging. Some of these are illustrated below:

1. The IBM Supply Chain Intelligence Suite includes the IBM Food Trust, which creates a secure, shared and permissioned record of transactions based on modules that allow for collaboration between supply chain actors. Blockchain technology stores digitised records in a decentralised and immutable manner, which can be easily accessed for compliance purposes.
2. Agworld offers easy to export reports and standardised product databases to assist in complying with regulation.
3. Croptracker is a farm management software for fruit and vegetable growers. It's record-keeping function allows records on spray, employees, harvest and irrigation to be easily uploaded and accessed, assisting in regulatory compliance.

USE CASE 4: PRECISION FARMING

Precision farming is a management approach to farming using real-time observation and GPS tracking systems to increase farm productivity, while reducing costs and optimising processes. Precision agriculture uses specialised equipment, software and IT services, and considers aspects such as soil type, terrain, weather, plant growth and yield data when managing crops. Real-time data on the conditions of the crops, soil and ambient air, local weather predictions, labour costs and equipment availability are all relevant to precision farming. A data exchange may facilitate the availability of real-time and GPS tracking data to support precision farming efforts.

Current market offerings where precision farming is prioritised include AgGateway, Trimble Agriculture, Farmers Edge, Topcon Agriculture, Raven Industries and Climate Corporation (Bayer). Some of these are:

1. AgGateway's ADAPT toolkit is designed to facilitate precision agriculture data by easily enabling interoperability between different software and hardware applications. ADAPT is an open-source project, managed by the AgGateway ADAPT Oversight Committee, with the goal of ensuring broad adoption of digital agriculture.
2. Trimble Agriculture offers CenterPoint RTX Correction Service, which works in tandem with Trimble GSS receivers for untethered surveying via satellite or cellular delivery. Likewise, they offer Section Control technology to maximise fields, Guidance Control to calculate the actual position of equipment, Steering Systems for maximum precision, and Flow and Application control for precise spraying, spreading, and seeding.
3. Farmers Edge provide real-time field data to monitor crops, optimise inputs and improve yields.
4. Topcon Agriculture offers Seed Drilling using real-time monitoring and control using present rates or imported treated maps for precision placement, as well as row crop planting control for accurate single spacing.

USE CASE 5: DATA SOVEREIGNTY

Data sovereignty entails respecting an individual or entity's rights to own and control their own data and includes measures to protect privacy and security and respect for local laws. It is a core use case for several agricultural data exchanges. Data sovereignty plays a key role in precision farming and requires that governance and technological frameworks protect farmer's rights to decide when and how to share data, for predetermined purposes. Providing authorisation and consent management tools that empower the farmer to take charge of what data they share, with whom and when, and by ensuring that farmers themselves benefit from sharing data, whether through reduced costs and workload, or increased productivity and profits is an essential aspect of data sovereignty. Respecting and enabling data sovereignty inspires trust and participation.

Current market offerings prioritising data sovereignty include JoinData, Agdatahub and Open Ag Data Alliance:

1. JoinData offers a data management platform for farmers to control who accesses their farm data, when and why. The JoinData platform is an easy-to-use platform where farmers can see everyone who can access their data and can control permissions by granting and withdrawing authorisation. Authorisation requests are limited by specific purposes, protected by law, and data privacy is protected by a "seal" function, whereby only the authorised recipient can access the data.
2. Agdatahub provides API-Agro, a data exchange platform for the agricultural supply chain and its stakeholders that works with a digital identity to provide consent management and secure data exchange. Its two core services are Consent: "a set of interoperable and secure modules dedicated to consent, from the identification of the actors to the notarization of the consents collected", and Exchange: "based on a sovereign and secure platform that connects issuers and acquirers of qualified data, in a framework of trust".
3. Open Ag Data Alliance is based on the principle of data sovereignty for the farmer whereby interoperability is enabled and secure. Public APIs are offered to farmers to choose trusted cloud providers, whilst retaining control over their data usage. The alliance offers an interoperability use case for a prescription map using the OADA REST API. Here, the farmer can authorise trusted agents to manage their data and can change cloud provider should they become unsatisfied.

USE CASE 6: SUSTAINABILITY AND ENVIRONMENTAL CONSERVATION

Specific on-farm data can be used to provide recommendations to reduce environmental impact of livestock by tracking feed dispensers, manure management, energy consumption and so on. This data can then be used to visualise the environmental impacts of the activities, including water and air quality, biodiversity, greenhouse gases, and carbon sequestration capacity, and to support decision making recommendations. Data exchanges can help to foster sustainable practices and responsible resource usage across a range of specific applications by facilitating data sharing and supply chain transparency for sustainable products, carbon credit markets, and sustainability metrics.

Current market offerings prioritising sustainability and environmental conservation include Institut d'Elevage, Alltech, Cool Farm Alliance, LetsGrow, DTN, TraceX Technologies, Ceres Imagining, Field to Market, FMC Precision Agriculture Solutions, Indigo Ag, Agrible, Terramera, AppHarvest and TruCarbon. Some of these are illustrated below:

1. Institut d'Elevage, offer CAP'2ER®, an Automated Calculation of Environmental Performance in Ruminant Livestock, which aims to assess the environmental impacts at the scale of a ruminant farm and per workshop (dairy cattle, meat cattle, meat sheep). It also offers a decision support tool for advisers/technicians carrying out detailed assessments of the environmental footprint of livestock including air quality, fossil fuel emissions and water quality to identify margins of progress and to build plans of action. It also measures positive indicators such as biodiversity maintenance and carbon storage. These assessments can then be used to advise breeders on more environmentally friendly practices.
2. Alltech offers Feeds EA™, which measures the environmental impact of feed production at the feed mill level, which is determined by calculating greenhouse gas emissions from production, cultivation, processing, energy utilization and transportation in feed manufacturing. Feeds EA™ can calculate emissions from a database of more than 300 ingredients, including raw materials, soya products, by-products and additives.
3. Cool Farm Alliance offers the Cool Farm Tool to measure herd or flock size, feed, manure management, energy use (kWh and fuel) and transport of feed and other inputs as well as water usage, to enable farmers to compare their usage and requirements and to minimise resources and environmental impacts.
4. LetsGrow offers the HortiFootprint Calculator developed in collaboration with MPS to measure the carbon footprint of horticultural production and assist in more sustainable decision-making.
5. DTN offers EcoField data, an agricultural and agronomic dataset that measures the impact of sustainable producer practices in the United States. The product allows for monitoring, calculation and reporting on sustainability metrics by grain suppliers, including carbon sequestration for SCOPE3 reporting, permitting growers to calculate the carbon footprint of their products.
6. TraceX Technologies offers sustainability management solutions to measure, monitor and reduce environmental impact, tracking key sustainability indicators such as carbon emissions, water usage, soil health and biodiversity markers. This data can assist businesses to set actionable, data-driven goals.
7. Ceres Imaging offer sustainability metrics to help with Greenhouse Gas (GHG) emissions reporting and customised recommendations to improve farm sustainability, including analytics on irrigation requirements, nutrient management plans, variable rate maps and disease forecasting and prevention.
8. Field to Market offers the Fieldprint Platform, an assessment framework for measuring and minimising the environmental impact of commodity crop production.

USE CASE 7: BIOSECURITY

Biosecurity is critical to agriculture as it provides measures to safeguard the health of crops, livestock, and ecosystems by preventing the spread of disease, pests and invasive species which directly threaten food security, productivity, and biodiversity. Data exchanges can support biosecurity measures by enabling the sharing of information, analysis, and dissemination of biosecurity risks. Some ways in which this can be achieved are through early detection and surveillance with real-time monitoring of vegetation health, climate conditions and pest movements using remote sensors such as satellites and drones; aggregating and visualising disease outbreaks to create disease maps to identify patterns and hotspots; drawing on data related to environmental conditions, crop types and pest populations to predict and assess risk; tracking produce (plants and animals) across borders to manage risk; sharing diagnostic data and test results for rapid confirmation and identification of pathogens; alerting relevant stakeholders about biosecurity risks; providing evidence of regulatory compliance; facilitating biosecurity audits and managing biosecurity incidents; and engaging communities and citizen scientists to contribute data. Overall, data exchanges can contribute to preparedness, response, and management of biosecurity risks.

Current market offerings prioritising pest and disease control (biosecurity) include The Climate Corporation:

1. The Climate Corporation (Bayer) offers Climate Fieldview, using satellite imagery to monitor crop disease and field health and to facilitate field scouting. The platform maps vegetation and monitors biomass in advanced colour for greater image detail, allowing for easier scouting and mapping of potential issues over time. The images can be compared with external data and easily shared with relevant stakeholders.

USE CASE 8: CLIMATE RESILIENCE

The effects of climate change, including volatile weather patterns, rising sea levels and rising temperatures, can have drastic effects on both industrial and small-scale farming. The increasing threat posed by climate change to food production and security by volatile weather, new pest and disease variants, and related supply chain and economic shocks has pushed agriculture towards sustainability and adaption measures. Climate resilience is the ability to foresee, tolerate, adapt to, and recover from climate change. Access to data on weather patterns and forecasts, and its effects on yields, for instance, is vital for small-holder farmers, who are most vulnerable to climate change and its related economic and environmental effects. Other applications include climate analysis and early warning systems, as well as knowledge sharing and research and innovation, which can lead to adaptive crop management, drought and flood management and resilient crop varieties. These data can also be used for risk assessment and management, financial support, and insurance purposes.

Current market offerings that prioritise climate resilience include Trace X Technologies:

1. TraceX Technologies offer products and services including blockchain traceability, sustainability management and carbon management. Measuring Greenhouse Gas emissions allows companies to implement carbon reduction strategies and to invest in carbon offset projects. Together, these solutions can contribute to a more climate resilient agricultural industry, as well as demonstrate regulatory compliance and respond to market demands for low-carbon products.

USE CASE 9: DATA-DRIVEN INSIGHTS (MARKETS AND DECISION-MAKING)

Data insights refer to the meaningful interpretations derived from data analysis, including statistical analysis, machine learning, and data visualisation techniques. Data insights can help farmers to uncover and understand patterns and facilitate better decision making. Agricultural data may include geospatial data for instance, which looks at field locations, soil types, weather patterns, and vegetation, collected via satellite imagery and ground sensors to allow for crop growth monitoring, irrigation optimisation and field operations planning.

Current market offerings that prioritise data-driven insights include Connecterra, DTN, Farmers Business Network (FBN), Granular (Corteva Agriscience), The Climate Corporation (Bayer), PrecisionHawk, SatSure and Sentera. Some of these are:

1. Connecterra offers the Connecterra app for data analytics and comparable farm data across eight interactive dashboards to uncover patterns, issues, and opportunities for improvement It also offers a Farm Timeline which provides a chronological view of farm events and operational changes, and an Impact Tracking tool, to help in better decision-making. The app also offers KPI insights and notifications and a Game Plan tool, to create collaborative action plans, monitor progress and measure results.
2. DTN offers FarmMarket data to streamline activities with a single data source, plan projects with current data, access relevant data and maximise investment. It also provides aggregated data on weather, soil, real estate, location, acreage, crop rotation, contact information, location, annual yields, pesticide applications etc.
3. Agrivi offers the Agrivi 360 Farm Advisory farm management software, providing real-time insights and data-driven recommendations. The product includes a central advisory platform for digital collaboration and data insights, real-time agronomy insights including crop progress and risks based on weather data, satellite data and applied agronomic practices. The data-driven advice includes customised recommendations based on past and present data, as well as upcoming forecasts. It also includes best practice analysis and farm profitability analysis.
4. Ag Data Commons, developed by the United States Department of Agriculture, offers Rangeland Analysis Platform (RAP), a free online application that provides simple and fast access to geospatial vegetation data for U.S. rangelands. The tool was developed to provide landowners, resource managers, conservationists and scientists access to data that can inform land management planning, decision-making, and the evaluation of outcomes. The maps and data provided by RAP are intended to be used alongside local knowledge and site-specific data to inform management actions that improve rangelands and wildlife habitat.

USE CASE 10: RISK MANAGEMENT

Agricultural data can be leveraged to identify, assess, and mitigate farmer and stakeholder risks. These risks include those related to climate and weather, pest and disease, market volatility and financial, operational, compliance and regulatory issues. It can also be used to minimise risks related to farm inputs and soil health. Data can be used to inform insurance decisions and risks related to technology adoption as well as emerging macroeconomic and geopolitical risks. Use cases include weather forecasts, disease models and yield predictions.

Current market offerings where risk management is prioritised include Ceres Imaging, Agrible, Climate Field View (Bayer), Resson and Bushel Farm. Some of these are:

1. Ceres Imaging offers a Risk Solutions product suite, designed for insurers and lenders based on data models from more than 11 billion individual plant-level measurements and more than 40 crop types. It can be used to streamline underwriting, improve claims responsiveness, and respond to risk in near-real time.
2. GIS offers a risk-management and decision-making tool using data visualisation and maps to display spatial correlation and patterns, and to enable communication between farm risk management stakeholders such as farmers, insurers and government agencies. For instance, remote sensor drones can be used to map hailstone damage to commodity crops, providing insurers with an easily accessible and rapid means for determining the extent of crop damage, while GIS permits sharing and collaboration and communication between stakeholders.

USE CASE 11: RESEARCH, INNOVATION AND COLLABORATION

Access to, and sharing of agricultural data is a key driver of research and innovation. In the last few years new technologies and products have emerged as a result of research and innovation that relies on agricultural data. Some of the areas where agricultural data have driven research includes, but not limited to the effectiveness of precision farming, sustainable farming practices, disease and pest control, soil health and nutrient management, climate resilience, water management, improved land management practices, agricultural policy and regulations.

Current market offerings where research, innovation and collaboration are prioritised include Connecterra Global Open Data for Agriculture (GODAN), BASF Agricultural Solutions, Syngenta, Aerofarms, Farmers Business Network (FBN) and Indigo Ag. Some of these are illustrated below:

1. The Connecterra platform offers data integration capabilities to capture, standardise and normalise individual farm data in real time, verified against trustworthy datasets for research and development purposes.
2. GODAN offers F1000Research, an Open Research publishing platform for life scientists, an open peer-reviewed and user-commenting system enabling rapid publication and author revisions. The platform enables open, public-interest research and collaboration.
3. AgGateway offers an Ag Industry Identification System (AGIIS), which contains agricultural eBusiness reference data and a repository for industry common data elements and unique identifiers, permitting efficient electronic interactions between companies, which enhances the possibility for collaboration. It is also working towards the harmonisation of eBusiness rules across various sectors to facilitate implementation of digital assets now and in the future. This work could facilitate collaboration across sectors.

USE CASE 12: REVENUE GENERATION FROM DATA

The monetisation of data can result from sharing or selling agricultural data to third parties for multiple purposes. Weather and climate data is of interest to precision farmers and AgTech providers alike, as well as to risk management firms, while supply chain data is of interest to consumers, which can add value to products for producers. Insurance providers and financial lenders can use data to set premiums and assess loans. Carbon credit schemes depend on data related to carbon sequestration and other environmental factors and sustainable practices. Water management services based on a combination of water usage, soil moisture and weather conditions can be offered to farmers to save water.

Current market offerings where data monetisation is prioritised include Farmobile and Farmers Business Network (FBN):

1. Farmobile offers farmers the possibility of monetising their data by using Farmobile Passive Uplink Connection (PUC) devices to collect data which can then be sold on the Farmobile DataStore exchange in which farmers licence single-use copies of data to approved third-party buyers. Participating farmers are anonymised; however they control authorisations, know who is accessing the data, and what the data is to be used for. Revenue is split with Farmobile, who offer the technology and facilitate the transactions.
2. Farmers Business Network's Gradable is a secure technology platform that enables grain transactions between producers and commercial buyers. It also provides services that facilitate the scoring, sourcing, and pricing of low-carbon grain, thus supporting environmental transparency and a market for sustainable grain, as well as strengthening relationships between grain buyers and producers.

USE CASE 13: BENCHMARKING

Data exchanges offer multiple benchmarking possibilities to the agricultural industry, which can assist in better decision-making, greater productivity, less waste, and more sustainable systems. Farmers can compare data on a range of areas with similar farms and regions to see how they fare. These can range anywhere from yields and inputs to operational costs, resource management and sustainability metrics. Benchmarking also extends to farming practices such as crop rotation and diversification and pest and disease management. For market purposes, farmers can improve market timing by comparing planting and harvesting dates with competitors as well as testing themselves against industry standards. Farmers can benchmark equipment utilisation, technology adoption and supply chain efficiency to improve performance. Finally, benchmarking data can be used to manage risk.

Market offerings where benchmarking is prioritised include Field to Market, Agriculture and Horticulture Development Board (AHDB) and AgWorld:

1. Field to Market's Fieldprint Platform enables annual sustainability benchmarking to measure environmental outcomes.
2. AHDB's Farmbench is a free, online benchmarking tool that allows farmers to make comparisons and evaluate performance to improve productivity and enhance profit. It is presently available for beef, lamb, dairy, combinable crop, potato, and sugar beet enterprises.
3. Agworld for growers is a farm management software including farm performance insights such as gross margin benchmarking.

6.1.3 Australian public datasets

This section summarises the publicly available Australian datasets into six groups that may be included in an AADX, namely (1) climatic and weather data; (2) federal and state government data; (3) research data; (4) markets data; (5) soils data; and (6) geo-spatial data. We refer the reader to the Appendix A6, where a comprehensive list of public datasets is provided.

Climatic and weather data

Australian Bureau of Meteorology (BOM)

BOM provides official statistics and forecasts regarding weather observations, such as rainfall, temperature, solar exposure, and various natural disasters. Given the close relationship between weather and agriculture, BOM data are expected to be valuable to DX participants.

Climdex

The Climdex project offers a range of climate extremes indices. These indices are annual or monthly statistics of modelled or observed climate data.

EAtlas

Provides environmental research, maps and data for tropical Australia.

Integrated Marine Observing System (IMOS)

IMOS offers the Australian Ocean Data Network (AODN), a data facility to underpin the national marine information infrastructure, including a geo-spatial portal, a metadata system, file formats, controlled vocabularies, file storage, servers, web services and data tools.

National Computational Infrastructure (NCI)

NCI manages one of the largest collections of curated research data in Australia including nationally significant datasets registered in the National Research Data Repository, such as international climate modelling datasets and time-series satellite imagery for the Australasian region and globally.

OzFlux

OzFlux is an ecosystem research network set up to provide Australian, New Zealand and global ecosystem modelling communities with consistent observations of energy, carbon and water exchange between the atmosphere and key Australian and New Zealand ecosystems.

Scientific Information for Landowners (SILO)

SILO, hosted by the Queensland Department of Environment and Science (DES), is a database of long-term Australian climate data. The daily meteorological datasets for a range of climate variables are excellent sources of data for analysis. SILO also provides spatially gridded data that were constructed from mathematical interpolation techniques.

Federal and State Government data

Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)

ABARES conducts independent research focussing on Australian agriculture, fisheries and forestry. In particular, ABARES provides data collected from the Australian Agricultural Census, which can be summarised at different spatial resolutions.

Australia Bureau of Statistics (ABS)

ABS is Australia's national statistical agency and an official source of independent, reliable data. Among the data available, agriculture and environment management data are most relevant to AADX.

Australian Government

Data.gov.au is the central source of Australian open government data. Over 100,000 anonymised public datasets published by various levels of government agencies can be found on this platform.

Australian Government Department of Agriculture, Fisheries and Forestry (ABARES)

ABARES provides data on Agriculture and Land, Biosecurity and Trade, and Science and Research.

Australian Government Department of Climate Change, Energy, the Environment and Water

The Australian Government Department of Climate Change, Energy, the Environment and Water hosts datasets on the Australian Government's Natural Resource Management (NRM) investments, which are contained in the National Landcare Program (NLP) Management Units. The NLP Management Units dataset provides authoritative reporting on the Australian Government's NRM investments, wherever Australian Government funded NRM investments are delivered.

Other sources of state and territory government data include:

New South Wales (NSW):

- NSW Department of Primary Industries.
- Data.NSW: Open portal datasets released by the NSW State Government.
- Sharing and Enabling Environmental Data (SEED) NSW: Datasets about NSW environmental data.
- NSW Environmental Protection Agency (EPA): provides data on waste, pollution, resource recovery and more.

South Australia:

- Department of Primary Industries and Regions, South Australia.

Victoria

- Agriculture Victoria.
- Data VIC: Open portal datasets released by the Victorian Government.

Queensland (QLD)

- QLD Open data portal: Open data released by the QLD Government.
- Department of Agriculture and Fisheries, QLD

Tasmania

- List data (TAS): Data portal for Tasmanian location-based information.
- Department of Natural Resources and Environment, Tasmania

Western Australia (WA)

- Department of Primary Industries and Regions, Western Australia
- Data WA: Western Australian public sector data.

Northern Territory (NT)

- Department of Industry, Tourism and Trade, NT
- Northern Territory open data portal: Datasets released openly by NT Government.

Research data

AgriFutures Australia

Offers data and reports on a range of topics relevant to Australian agriculture.

Australian Government Grains Research and Development (GRDC)

GRDC provides research reports, publications and data on grain production, agronomy, pest management and technology adoption.

Australian Research Data Commons (ARDC)

Research Data Australia under ARDC allows people to find data for research from over 100 Australian research bodies. Agricultural and Veterinary Sciences, Environmental Sciences and Earth Sciences data are available through ARDC.

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

The CSIRO Data Access Portal provides public access to research data published by CSIRO. The datasets within the category “Agricultural, veterinary and food sciences” are most relevant to AADX.

FedUni Research Data Catalogue

The FedUni research data catalogue provides public access to some of the research data they have collected. Out of all research themes, the Digital Agriculture and Natural Resource Management themes appear to be suitable for AADX.

Hort Innovation

Provides research publications, reports, fact sheets and more for growers and Australian horticulturists.

Online Farm Trials (OFT)

As a collaboration between Grains Research and Development Corporation (GRDC) and Centre for eResearch and Digital Innovation, OFT provides open and free access to on-farm, or field based, cropping research trial data and information. Since this platform provides field-based data, it is expected to be valuable to AADX participants.

Market data

Australian Bureau of Statistics (ABS)

The ABS offers data on the value of agricultural commodities produced in Australia, including final estimates of gross and local values of production of principal agricultural commodities for Australia and its states and territories.

Australian Food and Grocery Council

The Australian Food and Grocery Council provides an annual State of the Industry report containing data on imports and exports, business count and capital investment, regional employment, employment, AFG turnover, domestic turnover and total turnover.

Australian Government Department of Agriculture, Fisheries and Forestry (ABARES)

ABARES offers a weekly commodity price update, including links to world agricultural prices, Australian agricultural prices, and Australian horticultural prices and weekly price movements on selected world indicator prices, selected Australian grain prices, selected domestic livestock indicator prices and Global Dairy Trade (GDT) weighted average prices.

Australian Wine and Grape Authority (Wine Australia)

Wine Australia provides Market Bulletin, which features analysis of the global wine market and country-specific categories for exploring wine production, consumption and more. It also offers Market Insights, with a range of data and analyses relevant to the global wine market.

Australian Wool Exchange (AWEX)

AWEX Market Information Services provides weekly, monthly and annual industry market reports for both instantaneous and historical wool market data. The information outlined in reports can be used to benchmark the Australian wool market globally.

Fisheries Research and Development Corporation (FRDC)

FRDC offers market data on the gross value of Australian seafood production, including data on Australian seafood data by value and volume, including imports and exports and species-specific data.

Hort Innovation

Hort Innovation provides an annual Australian Horticulture Statistics Handbook with the most comprehensive and current data available across the Australian horticulture sector, including international trade statistics.

Meat & Livestock Australia (MLA)

MLA's Statistics database contains data on pricing, production, and trade regarding livestock from Australia and around the world.

Rural Bank

Provides monthly commentary on production and pricing trends for Australian agriculture that serves as both an overview of current trends and an outlook for the near future. Rural Bank offers analyses of production and pricing trends for Australian horticulture producers, cattle producers, broad acre farmers, sheep producers, wool producers, and dairy producers. It also offers data on Australian farmland values, agricultural outlooks, and agricultural trade.

Soils data

Australian Soil Resource Information System (ASRIS)

Offers links to download, and reports, interpretations, and tables for the Atlas of Australian Soils (CSIRO) and its digital version (Bureau of Rural Science). ASRIS provides online access to publicly available data and information on soil and land resources (including polygon mapping at various scales, reference sites and analytical data, and interpreted national grid products) in a consistent format across Australia. A number of datasets are available to view and download here.

CSIRO National Soil Site Database

Currently contains descriptions of over 21, 000 soil site investigations. The data includes morphological descriptions, chemical, physical and mineralogical properties and spectral predictions, along with soil specimen management data. The database and the Australian National Soil Archive provide the foundation for the development of a national soil spectral library and also support TERN Landscapes national soil property modelling through a federated collation of available soil databases.

SEED The Central Resource for Sharing and Enabling Environmental Data in NSW

SEED provides the Australian Soil Classification (ASC) soil type map of NSW, which identifies the dominant soil types across NSW using the ASC at Order level and incorporates 55 different datasets of varying scales across the state. They also offer the SEED map, including other natural resource databases such as vegetation.

Soil and Landscape Grid of Australia (SLGA)

SLGA provides freely available data about soil and landscape attributes within Australia, which are considered important aspects of agriculture.

Soil Science Australia

Provides links to soil data, maps and information sources from national and state/territory levels and the from CSIRO.

Geo-Spatial data

Australian Government Data

Provides the NationalMap, a visualisation tool for open data from Australian Government agencies, facilitating geospatial data exploration and use.

Australian Spatial Data Infrastructure (ASDI)

ASDI is a national framework for linking users with providers of spatial information. ASDI comprises the people, policies and technologies necessary to enable the use of spatially referenced data through all levels of government, the private sector, non-profit organisations and academia.

Earth Engine Data Catalogue

Earth Engine includes historical imagery and scientific datasets for Earth science analysis. Among these, the climate and weather data, satellite images and geophysical data would be valuable additions to AADX.

Digital Earth Australia

Digital Earth Australia (DEA) uses spatial data and images recorded by satellites to detect physical changes across Australia.

Geoscience Australia

Geoscience Australia's Interactive Maps is a discovery and exploration view of Geoscience Australia's geo-spatial data products and web services. It provides access to the wealth of curated information, content organised into science disciplines and decision support themes, which is easy to navigate and linked to related information. Data is presented in dynamic maps, links to metadata, map printing and access to Open Geospatial Consortium web services. Some maps have additional tools providing specific functionality.

University of Melbourne

Provides Geospatial (GIS), Spatial data and map resources.

6.2 Summary of Key Findings

This section analyses the key findings from the research with respect to the research objectives. Specifically, this section aligns with the key research questions: (1) what is the impact of a DX on accelerating adoption of AgTechs? And (2) what are the relevant public datasets that could be included in the AADX?

What is the impact of a DX on accelerating adoption of AgTechs?

- Primary data emphasised the importance of carefully considering which use cases should be prioritised, this idea was echoed in the grey literature. Use cases ought to garner interest from a community of early adopters who will enable the data exchange to be meaningfully tested. **Use cases that exemplify the end-to-end impact of a DX will appeal to a greater range of potential DX participants and should be prioritised.**
- **The development of end-to-end use cases** can be achieved by considering needs that cut across most sectors within the agricultural supply chain, for example, traceability of produce, and regulatory compliance. This will not only have the potential to attract the most DX participants but **will have the most positive flow on effect on accelerating adoption of agricultural technology by stakeholders in the supply chain**.
- The use cases encountered in this study illustrate the impact of data-driven decisions on stakeholders along the supply chain, from producers to consumers. They highlight the positive impact and value-add of collaboration and suggest ways that primary producers can benefit from data sharing and hence be encouraged to participate in a DX. **The added value and broad impact of use cases should be central to the development of the AADX.**

What are the relevant public datasets that could be included in the AADX?

- The top five data sources prioritised by AgTechs in this study are (1) data from producers and processers (59%), (2) data from other AgTechs (47%), (3) open data (34%), (4) government data (34%), and (5) domestic and global markets data (28%). The AADX should consider strategies that will facilitate the inclusion of these data on the AADX[23].
- Six groups of publicly available data sources have been identified whose inclusion in the AADX will prove beneficial to DX participants and should therefore be prioritised. These are (1) weather data; (2) federal and state government data; (3) research data; (4) markets data; (5) soils data; and (6) geo-spatial data.

23 Percentages in bracket indicate the proportion of AgTechs who selected a particular data source.

7 Conclusion

"...you can't build algorithms in the future on static data. It's useless. You need behavioural data." (DX interviewee)

Successful DXs have been built on good governance and good relationships. Broadly speaking, data exchanges that enable the free flow of information through open standards allow for mutual benefit and enhance trust and participation. An environment of optimal participation creates new possibilities for finding common needs and interests, and for working together in a dynamic digital community. In this study, emphasis has been placed on the perspective of the Australian AgTech sector and other existing DXs with regards to an Australian agricultural DX. In this section, we summarise the key research findings that should inform the design of an AADX and reflect on the role DXs in general might play in the future of our agricultural industry.

7.1 Key Considerations for the Design of an AADX

The agricultural supply chain is complex and has numerous stakeholders, including primary producers, the retail, financial, transport and insurance sectors as well as AgTechs, who play an essential role within the supply chain. Data sharing within the agricultural supply chain is considered by all stakeholders, in this study, as having a positive flow on effect on the industry. In particular, the Australian AgTech sector sees data as a primary driver of innovation. However, agricultural data is often siloed and the means for accessing this data is not streamlined for the whole of industry, even while certain sectors within the industry have been resourceful in their approach to sharing data.

There are numerous opportunities within the context of data sharing where an AADX can play a significant role in enabling innovation and productivity amongst AgTechs, by mitigating challenges of data integration and interoperability, and supporting data management and its access control. This could lead to service benefits such as enhanced data-driven technologies, standardisation of data and flexibility of engagement with data by stakeholders.

This research found that the AADX can play a significant role in data sharing in Australian agriculture, if numerous conditions are met. Firstly, it found that successful DXs rely on the establishment of good relationships that encourage participation and the free flow of data. These relationships require genuine multistakeholder consultation by adopting bottom-up approaches. It also requires the AADX to take on an intermediary role in mediating divergent, and possibly conflicting, interests amongst various stakeholders in the supply chain. This requires a broad view of the industry that takes account of the complexity of the supply chain where for example, farmers can be both the primary producers of data and the ultimate consumers of AgTech. While some stakeholders will have a greater role to play in data sharing, the needs and interests of all must be considered from a broad and integrated perspective to avoid siloed approaches that dampen the possibility for an open and flourishing digital community.

Secondly, an AADX must articulate their value proposition in terms of product offerings and services, demonstrating a clear need through use cases. Successful DXs have expressed the need to avoid competition, real or perceived, with AgTechs as this brews suspicion and lack of trust. Adopting a non-competitive approach naturally facilitates the priority service benefit, as seen by AgTechs, of integration and interoperability as the basis for enabling data sharing. Such a service should embed secure, efficient and permissioned exchange of data that respects the rights of data producers and creators, including those of the farmer to control who, when and for what purposes their data is used. Easy-to-use interfaces and data connectors will be crucial to ensure a wider appeal to various stakeholders in the supply chain. Further, an AADX should offer modular services that will enable different stakeholders with different needs to pick and choose how they may interact with a DX in the most beneficial way to them.

Thirdly, an institutional framework that appeals to a broad spectrum should be adopted by the AADX. In the process of establishing these institutional frameworks it is recommended that an AADX engages in ongoing, multistakeholder consultations that inform a model that serves the needs and interests of the broadest possible section of the supply chain. This may extend beyond AgTechs to other stakeholders in the supply chain, including primary producers and the retail, financial, transport and insurance sectors, amongst others. Building a hybrid, public-private initiative in collaboration with representative industry bodies from the ground up and based on input from these consultations will strengthen its claims to servicing the national agricultural industry. It will also allow for potential conflicts to be unearthed and addressed prior to implementation, further cementing the intermediary role of the DX and its value to the industry. Transparency in the DX governance structure will also be key to gaining and maintaining trust. This may be further enhanced by ensuring logging of data activities by the AADX to ensure traceability of data use, or by embedding blockchain technology. This will help the AADX to demonstrate data authenticity, correct handling, trustworthiness and reliability. This is likely to win the trust of agricultural stakeholders and overcome hesitation to adoption.

Finally, in demonstrating the need for, and value of, an AADX, the role of use cases will be crucial. These should be broad ranging and end-to-end to show how a DX can impact the whole of supply chain, ideally in ways that ensure the benefits flow across the industry, in one form or another. These will need to be shown through the development of prototype applications. This ought to be complemented by utilising and negotiating access to publicly available datasets to demonstrate the usefulness of a DX as a key resource for data sharing. Where these can be successfully achieved, an AADX is likely to have a cascade effect in convincing relevant stakeholders and the broader public of its intrinsic value and necessity.

Despite the realisable and desirable potential for an AADX, there are risks to consider; successfully mitigating these risks is likely to cement the relevance of an AADX to the industry. Firstly, data monopolies leading to power concentration may create conditions for a complete dominance and control of the data market by a single entity—the DX. This is a risk that can ultimately, paradoxically, lead to the failure of an AADX. This risk can be mitigated by ensuring proper checks and balances through clear and transparent governance structures. Secondly, technical risks related to data quality, system reliability, system security, interoperability and user experience can affect trust, confidence and usefulness of the AADX. Abiding by the relevant data regulations, adopting state-of-the-art standards, as well as developing comprehensive data policies and strictly enforcing them, are sure ways to mitigate these risks.

Achieving these key design considerations are likely to assure a sustainable AADX that addresses the current needs of the sector and positions it strategically to cater for the future demands of the agricultural industry.

7.2 The Future of Data Exchanges in Agriculture

"We are in transition from big data to shared data. Public-private data exchanges will play a major role in accelerating that transition." (World Economic Forum, December 15, 2021)

The future of DXs is yet to be written; however, it seems obvious that a culture of data sharing will drive new innovations that will likely create market disruptions. There is a possibility that a data exchange that creates conducive conditions for data sharing could undermine current hierarchies based on the accumulation and privatisation of data, whilst enabling the democratisation of innovations through the use and reuse of data. This would open the AgTech market to new players and foster an environment of rapid innovation.

Creating a safe culture of data sharing with the right protections and governance is expected to propel the data economy by expediting the realisation of value from the vast and thus-far largely untapped potential of data. There is no doubt that environmental, ethical, regulatory and consumer-driven demands for ethically sourced and sustainably grown produce will be key drivers. This is anticipated to cover the length and breadth of the supply chain, extending beyond geo-political boundaries.

Appendices

A1 Indicative DX Qualitative Interview Questions

Institutional

1. When was your organisation established?
2. How many employees does your organisation have?
3. In which geographies does your organisation operate?
4. What is your overall mission?
5. What is your organisation's ownership structure?
6. Was the form of your ownership structure driven in any way by your data providers and/or data consumers?
7. What is your commercial relationship with your data providers and with your data consumers?

Socio-economic

1. To what extent would you regard data exchange as a market disruption? How is this manifested?
2. What is your go to market value proposition?
3. How do you distinguish between data providers and data consumers?
4. What value-add/benefits do you provide to your data providers and consumers?
5. What value is monetised by you, your provider and your consumers and how?
6. What are examples of opportunities that have been created for providers and consumers that would not have been possible without your services?
7. What are your core target markets now, and do you have plans to expand upon these?
8. What participation barriers/inhibitors do you face both backwards to your providers and forwards to your consumers?
9. How do your markets relate to your service offerings?
10. Do you face competition either direct (other DX providers) or indirect (other products meeting similar needs)?

Operational

1. Who are your data providers? Name and/or type.
2. What other sources of data do you use/support?
3. How do you ensure security of data backwards to providers and onwards to consumers?
4. What risks are of concern to you as a data exchange and to your providers and consumers?
5. What governance procedures do you have in place?
6. What issues of trust are there and how do you maintain this?
7. What legal and regulatory frameworks are you subject to and how do you address them?

Technological

1. What is your technical architecture?
2. What quality standards do you adhere to? Provide examples.
3. What data standards and ontological framework do you use?

Respondent detail

4. What is your role within your organisation?

A2 Indicative AgTech Qualitative Interview Questions

Institutional

1. When was your organisation established?
2. How many employees does your organisation have?
3. In which geographies (domestic and international) does your organisation operate?
4. What is your overall mission?
5. What is your organisation's ownership structure?

Socio-economic

1. What is your go to market value proposition?
2. What is you core service offering?
3. What are your core target markets now, and do you have plans to expand upon these?
4. Do you provide a product/solution that shares data between multiple platforms?
5. Do you provide a product/service that consumes data from third-party sources to provide functionality?
6. What data sources do you use or would like to use and what value does this/would this add to your business?
7. What participation barriers/inhibitors do you face that relate to datasets?
8. Do you think that a data exchange for agricultural data would add value to your business?
9. Would you regard data exchange as a market disruption? How would this be manifested?
10. Would you regard a data exchange as competitive to any of your offerings?
11. What business opportunities would you want a common data platform to enable?
12. To justify your business paying for access, what facilities would a data exchange need to provide?
13. What payment model would be preferable for your business?

Operational

14. Does your business experience issues with the quality of data sourced from third parties?
15. What business model for integrating with a data exchange would be ideal for your business?
16. What ownership model would you see as preferable for a data exchange?
17. What do you consider to be the barriers to your participation in a data exchange?
18. Who are your data providers? Name and/or type.
19. What other sources of data do you use/support?
20. Do you currently monetise your own data or have plans to do so in future?
21. How do you ensure security of data?
22. What risks associated with a data exchange would be of concern to you?
23. What governance procedures do you have in place?
24. What issues of trust are there between you and data suppliers whether customer or third-party and how do you maintain this?
25. What legal and regulatory frameworks with respect to data are you subject to and how do you address them?
26. In what timeframe would you anticipate collaborating with a data exchange?

Technological

27. What is your technical architecture with respect to data?
28. What methods do you currently use to share with and/or consume data from third parties and/or are likely to use in the future?
29. What quality standards do you adhere to? Provide examples
30. What data standards and ontological framework do you use?
31. What technical model for integrating with a data exchange would be ideal for your business?

Respondent detail

32. What is your role within your organisation?

A3 AgTech Quantitative Survey Questions[24]

Section A: Personal demographics

To start off with, please tell us, which of the following age groups do you fall into?

- 17 and under
- 18 - 24 yrs.
- 25 - 34 yrs.
- 35 - 44 yrs.
- 45 - 54 yrs.
- 55 - 64 yrs.
- 65 + yrs.

And you identify as:

- Male
- Female

An alternative identity (please specify)

- Prefer not to say

How long have you been working in the AgTech industry?

- Less than 12 months
- 1 to 3 years
- 3 to 5 years
- 5 to 10 years
- 10 to 15 years
- 15+ years

Section B: Business Profile

We now have a few questions for you about the business you work at.

1. Which of the following best describes the role(s) you hold/are employed in? You can choose more than one response. Please select **all** that apply:

    - Founder/CEO
    - Manager
    - Chief Technical Officer
    - Technical developer
    - PR/Marketing/Advertising/Sales Manager
    - Other (please specify)

24 Please note that survey questions were coded on the Qualtrics platform, and do appear differently on the survey platform.

2. Approximately, how many people would you say also currently work at that business in total (this includes those working full-time and part-time):

   - Less than 4 people
   - 5 to 19 people
   - 20 to 50 people
   - 51 to 100 people
   - 101 to 150 people
   - 151 to 199 people
   - 200 people or more

3. And, how long has the business been in operation?

   - Less than 1 year
   - 1 to 3 years
   - 3 to 5 years
   - 5 to 10 years
   - 10 to 20 years
   - More than 20 years

4. What is the approximate turnover of your business

   - Less than AU$500,000.00
   - Between AU$500,000.00 and AU$ 1 million
   - Between AU$ 1 million and AU$ 5 million
   - Between AU$ 5 million and AU$ 10 million
   - Between AU$ 10 million and AU$ 20 million
   - Between AU$ 20 million and AU$ 50 million
   - Between AU$ 50 million and AU$ 100 million
   - More than AU$ 100 million
   - Prefer not to say/Don't know

5. Which of the following sectors does your business work within? *Please select all that apply:*

   - AgriTech
   - Aquaculture
   - Agistment services (Cattle and livestock)
   - Beef
   - Cotton
   - Milk
   - Eggs
   - Food innovation
   - Fruits
   - Fodder and grass
   - Plants and flowers
   - Game
   - Honey
   - Horticulture (Plants and flowers)
   - Sheep, lamb, cattle and calves
   - Nuts
   - Oilseeds
   - Pigs
   - Poultry (for slaughter and egg laying)
   - Pulse grains
   - Barley, oats, rice, sorghum and cereal grains
   - Other grains
   - Sugar cane
   - Vegetables
   - Fisheries
   - Wine
   - Wool
   - Wheat
   - Pets and live animals
   - Horse Agistment Services
   - Others [Please specify]

6. And, considering the sectors your business works in, which of the following services does your business offer? *Please select all that apply*:

In-field technologies

- Small farmer Solutions
- Soil
- Seed Tech
- Carbon
- Connectivity
- Bio-Stimulants/Fertilisers
- Bio-Pesticides
- Apps
- Sensors
- Insects and Pollination
- Irrigation and Fertigation
- Imagery Analytics
- IoT and Analytics Solutions
- Input Efficiencies
- Field Monitoring and IoT Solutions
- Imagery Platforms
- Imaging Service Provision
- Scouting
- Labour Management
- Farm Efficiency Optimisation
- Climate
- Pest, Disease and Weed Management
- Sustainability
- Crop Health/Science
- Intensive Agriculture
- Natural Capital

Software/IT

- Agronomy Software
- Crop Management Software
- Farm Management Platforms
- Farm Accounting Software
- Business Intelligence
- Communications / Connectivity
- Water Management Software
- Optimisation
- System Integration
- Decision Support systems / Artificial Intelligence
- Data Analytics / Data Storage
- Big Data Provision
- Industry Intelligence
- AgTech Media
- Markets/Information

Equipment

- Farm Machinery and Equipment
- Automation
- Autonomous
- Robotics
- Equipment Optimisation
- UAV
- UAV Application
- Variable Rate Technologies

Services

- Development Tools
- Chemical analysis
- Service Provision
- Startup Resources
- IP Services
- Education and Training
- Marketing /Advertising

Supply chain

- Finance/Insurance
- Traceability/Safety
- Post-Harvest
- Grain Storage and Handling
- Processing and Packaging
- Food Recovery
- Crop Market Platform
- Trading/Sales Platform
- Sustainability
- Retail
- Supply Chain

Animal

- Animal Genetics
- Feed Tech
- Animal Health Technologies
- Animal Monitoring
- Livestock Farm Managements
- Animal Market Platforms
- Waste Management
- Veterinary Services
- Aquaculture
- Fisheries

Startup and Investment

- Startup Programs
- Investment and Venture Capital
- Others (Please specify)

7. Thinking about your business currently, how strongly would you agree or disagree that:

Items	Strategic business performance				
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
Our business has a strong presence in the market					
Marketing efforts have increased awareness of the company/firm and its brand					
Our business has been able to positively respond to challenges made by our competitors					
Our business has continuously improved financial performance					
Our business has continued to build a strong relationship with our customers					
Our business has continued to build a strong relationship with our external stakeholders					
Our business has achieved its strategic goals in term of achieving high productivity					
Our business has achieved its strategic goals in term of achieving a larger market share					

Section C: Business and data

8. Which of the following do you have within your organisation?

Documented data management processes (to assuring data quality)
Documented data governance processes (to ensure compliance with regulatory frameworks)
Documented data analysis processes (to derive value/insights from the data)
Ad-hoc processes to manage data governance or analysis
None of the above

9. We now have a few statements about the access and use of data **as part of your business practice more generally**. These include the access and use of data to deliver services to your customers, or data required in the operation of your business. How strongly would you agree or disagree with the following statements:

Items	Data digitalisation/FAIR data compliance				
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
I can easily and regularly find the required data that are:					
• relevant to business/products/services, useful and what I was looking for					
• reliable, authentic, and trustworthy					
• well documented, maintained, and up to date					
• understandable, self-explanatory, and easy to follow					
The metadata (i.e., details about the data, data title, description, subject, keywords, format, references etc.) are always:					
• understandable, easy to follow and self-explanatory					
• reliable, authentic, and trustworthy					
• well documented and maintained					
• helpful to easily locate the actual dataset					
• helpful to understand the data objectives (i.e., purpose, role, use, function etc.)					

The required data is usually easily accessible:
• by following the online/website location address or unique web link
• by following users' authentication/ verification/ permission/authorisation guidelines
• if I have the right program or connection device

If I cannot find the data I require, or they are no longer available, I can usually find:
• some information related to the data
• contact details for the data creators, owners, or custodians
• references and links to related or similar data

The required/relevant data and details about data are usually:
• in a file format that I can easily use with my own technology
• clearly explained, standardised, and in recognised format(s) *(For example, date formats and units of measure are not ambiguous)*
• understandable and reveals exact and accurate meaning *(For example, species names and geographic locations are quite clear)*
• in a consistent file format and data structure, when from the same data source

If I want to reuse the data that I have found, I usually:
• understand the access conditions and have easy steps to follow
• am familiar with how the data were obtained and why they were originally collected
• understand the limitations of the data when using them for my/our purposes
• have information about data licenses, attribution, or other requirements

10. With regard to business data management, how strongly would you agree or disagree with the following statements:

Items	Innovativeness					
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
• We seek out new ways to do things						
• We are creative in how we use and share data						
• We actively seek new sources of data						
• We have introduced new processes over the last 5 years						
• understandable, self-explanatory, and easy to follow						

11. Thinking about your business, do you typically create, share, or consume data in the process of conducting regular business? You can choose multiple responses.

- We generate data
- We share data
- We use data to generate insights
- We share insights generated from data
- We do not do any of the above **but plan to in the future**
- We do not do any of the above and **do not plan to in the future**

12. How many external stakeholders do you currently share data with?

- 0 external stakeholder
- 1 to 5 external stakeholders
- 6 to 10 external stakeholders
- 11-15 external stakeholders
- 16-20 external stakeholders
- 21+ external stakeholders

13. We would now like to ask you a few questions about how your business uses and shares data. Which of the following methods do you currently use, or would consider using in the future, to **store data within your organisation**?

	Currently using and will keep using in the future	Currently using but is considering not to use in the future	Not currently using but would consider in the future	Not currently using and do not plan to use in the future	Not sure
Hard copy filing systems (folders and documents)	○	○	○	○	○
Digitised filing systems (through CSV files, Excel, PDF files)	○	○	○	○	○
Data base systems (SQL, Oracle, SAP, etc)	○	○	○	○	○
Others	○	○	○	○	○

Please share further details regarding your choice or specify details of other methods

14. Which of the following methods do you currently use, or would you consider using in the future, **to share data with relevant stakeholders**?

	Currently using and will keep using in the future	Currently using but is considering not to use in the future	Not currently using but would consider in the future	Not currently using and do not plan to use in the future	Not sure
Application Programming Interface (API)/ Secure file transfer sites	○	○	○	○	○
Emails or sharing sites (WeShare, etc)	○	○	○	○	○
Hard-drives or USB storage devices	○	○	○	○	○
Others	○	○	○	○	○

Please share further details regarding your choice or specify details of other methods

15. Thinking about how you coordinate or share data between your business and your external stakeholder (who can be data providers and/ or data consumers), how strongly would you agree or disagree with the following….?:

Items	Integration between AgTech vendors-data supplier(s)				
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
• I feel we generally have a close level of coordination between the organisations					
• I feel data coordination activities are generally well integrated within both organisations					
• There is generally a perfect integration of data coordination activities on both sides					
• Data integration is generally well planned, efficient, safe, and secure on both sides					
• Inbound and outbound distribution of data is generally well integrated					

Adapted and modified from: Chen et al, (2004); Abdallah et al., (2017)

Section D: Data Sharing Platform IDEA

We would now like you to think about the prospect of using a data exchange platform to share data. The below description provides a broad overview of what a data exchange platform is.

A Data Exchange may be considered as a platform that facilitates the secure and controlled dissemination, acquisition, sharing and integration of datasets, to create business value for the producers and the consumers of the data.

Data exchange may occur as peer to peer sharing of data between or within entities; private data exchange within an industry vertical or functional area; or within an open data marketplace. Participants can decide how much data they share and use, and how often they share and use.

Such a platform may support agricultural businesses by providing access to traceable and secure data helping to inform decision making.

16. Given the description of a data exchange, does your organisation participate in any form of a data exchange platform?
    - Yes, an Australian data exchange [we provide textbox here for people to describe]
    - Yes, an Overseas data exchange [we provide textbox here for people to describe]
    - No

Section E: Overall impressions

17. Thinking about the idea for a data exchange platform you have just read, in the box below, please tell us your overall thoughts about the idea (could be positive or negative).
18. How strongly would you agree or disagree that a data exchange platform is:

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
• important for your business to achieve its current goals					
• essential for your business to succeed in the future					

19. If a data exchange was developed, how strongly do you agree or disagree that the data exchange would...

Items	Perceived attributes of data exchange				
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
Relative advantage					
• increase our productivity and service quality					
• decrease our costs for providing products and services					
• provide better information on which to base decisions					

20. If a data exchange was developed, how strongly do you agree or disagree that

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
Adaptiveness					
• Your business is mentally ready, professionally trained and technically equipped to cope with the change					
• Your business can easily adapt with new systems, varieties, techniques, and/or technologies to maintain profitability					
• Your business can adapt to improve its overall business performance					
• Your business would adopt a data exchange platform as soon as it becomes available in Australia					

Section F: Specific evaluations

21. Thinking about the idea for a data exchange that you read above, what information would you require before you decided to participate on such a platform? Please pick the three most important things to you and your business.

- The impact it is forecast to have on our business (e.g., direct or indirect revenue)
- How compatible it is with your current systems (technical compatibility)
- How well it fits with your current working approach
- The governance and operating models that will be followed
- The security standards that will be followed
- The standards for data quality that will be followed
- The price of participating
- The terms and conditions for participating (e.g., who owns the data)
- What types of data will be available
- Who else is using the data exchange
- The kind of skills staff will need to use the platform

22. Who would be the **best entity to manage** the platform: (Please select only one)

- The Agrifood industry
- University/Research Institute
- Private commercial
- Cooperative
- Government
- Not-for-profit company
- Other

Please explain your selection or share other thoughts relating to data exchange ownership structures.

23. What would be the **best payment method/model** for you to consider participating? (Please select only one)

    - An agreed annual fixed or tiered membership fee structure
    - Tiered subscription per application programming interface (API) connection
      where the published price, based on the software package and number of user licenses selected by the customer, is to be paid for each API i.e., set of defined rules that enable different applications to communicate with each other.
    - Charge per data volume transferred
      i.e., based on the size of datasets that an organisation has collected to be analysed and processed
    - I do not have an opinion on a specific payment method/model
    - I am not willing to pay to participate
    - Other – please specify

24. If the data exchange was developed, which of the following data sources should it integrate? Please pick three that are most important to your business.

    - Government (e.g., land use data, fuel pricing data, wage price data etc from data.gov.au)
    - Producer/Processor (e.g., soil sample data, livestock breed data, farm yield data etc from primary producers and processors)
    - Open (e.g., open data sources from research and non-governmental institutions such as agricultural research data from universities, for instance Smart farm data from Charles Sturt University)
    - Other AgTech(e.g., data from other AgTech vendors within the agricultural business supply chain)
    - International (e.g., data from overseas primary producers and businesses within the agricultural supply chain)
    - Market (e.g., access to domestic and global agricultural market)
    - Service providers (e.g., access to ancillary service providers within the agricultural supply chain such as banks, insurance etc)
    - Regulatory and compliance (e.g., access to data from regulatory and compliance bodies across states and overseas)
    - Other (please specify)

Section H: Closing

25. Are you interested to know about the outcome of this research?

    - Yes, I want to know about the outcomes
    - Yes, I want to know about the outcomes and am willing to participate in further research
    - No

    If yes, please provide your email below

26. How did you hear about this survey?

    - I was invited by a member of the research team
    - I was referred by another Agri business/stakeholder
    - Other (Please specify)

A4 AgTech Survey Respondents' Sentiment Towards an AADX

Table 3 Cross tabulation of survey respondents' sentiment towards AADX with their business characteristics

	Negative	No sentiment	Positive
Business size			
<20	1 (8%)	1 (8%)	10 (83%)
20-100	2 (17%)	1 (8%)	9 (75%)
>100	1 (13%)	3 (38%)	4 (50%)
Years in operation			
<10	1 (6%)	2 (12%)	14 (82%)
10+	3 (20%)	3 (20%)	9 (60%)
Share data			
No	1 (9%)	3 (27%)	7 (64%)
Yes	3 (14%)	2 (10%)	16 (76%)
No. external entities			
<21	1 (6%)	3 (19%)	12 (75%)
21+	3 (19%)	2 (13%)	11 (69%)

A5 List of Relevant Standards

1. ISO 8000-1:2022 Data quality — Part 1: Overview https://www.iso.org/standard/81745.html
2. ISO 8000-8:2015 Data quality — Part 8: Information and data quality: Concepts and measuring https://www.iso.org/standard/60805.html
3. ISO/TS 8000-82:2022 Data quality — Part 82: Data quality assessment: Creating data rules https://www.iso.org/standard/78707.html
4. ISO/TS 8000-81:2021 Data quality — Part 81: Data quality assessment: Profiling https://www.iso.org/standard/77227.html
5. ISO/TS 8000-60:2017 Data quality — Part 60: Data quality management: Overview https://www.iso.org/standard/66234.html
6. ISO 8000-61:2016 Data quality — Part 61: Data quality management: Process reference model https://www.iso.org/standard/63086.html
7. ISO 8000-150:2022 Data quality — Part 150: Data quality management: Roles and responsibilities https://www.iso.org/standard/80753.html
8. ISO 9000 family Quality management https://www.iso.org/iso-9001-quality-management.html
9. ISO 9001:2015 Quality management systems — Requirements https://www.iso.org/standard/62085.html
10. ISO/TS 9002:2016 Quality management systems — Guidelines for the application of ISO 9001:2015 https://www.iso.org/standard/66204.html
11. ISO 10005:2018 Quality management — Guidelines for quality plans https://www.iso.org/standard/70398.html
12. ISO/CD 10009 Quality management — Guidance for quality tools and their application https://www.iso.org/standard/84157.html
13. ISO/IEC 25000:2014 Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Guide to SQuaRE https://www.iso.org/standard/64764.html
14. ISO/IEC 25020:2019 Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Quality measurement framework https://www.iso.org/standard/72117.html
15. ISO/IEC 25021:2012 Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Quality measure elements https://www.iso.org/standard/55477.html
16. ISO/IEC 25022:2016 Systems and software engineering — Systems and software quality requirements and evaluation (SQuaRE) — Measurement of quality in use https://www.iso.org/standard/35746.html
17. ISO/IEC 25023:2016 Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Measurement of system and software product quality https://www.iso.org/standard/35747.html
18. ISO/IEC 25024:2015 Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Measurement of data quality https://www.iso.org/standard/35749.html
19. ISO/IEC TS 25025:2021 Information technology — Systems and software Quality Requirements and Evaluation (SQuaRE) — Measurement of IT service quality https://www.iso.org/standard/74569.html
20. ISO/IEC/IEEE 32675:2022 Information technology — DevOps — Building reliable and secure systems including application build, package and deployment https://www.iso.org/standard/83670.html

21. ISO/IEC 27000:2018 Information technology — Security techniques — Information security management systems — Overview and vocabulary https://www.iso.org/standard/73906.html
22. ISO/IEC 27001 Information security management https://www.iso.org/isoiec-27001-information-security.html
23. ISO/IEC 27002:2022 Information security, cybersecurity and privacy protection — Information security controls https://www.iso.org/standard/75652.html
24. ISO/IEC 27005:2018 Information technology — Security techniques — Information security risk management https://www.iso.org/standard/75281.html
25. ISO/IEC 27701:2019 Security techniques — Extension to ISO/IEC 27001 and ISO/IEC 27002 for privacy information management — Requirements and guidelines https://www.iso.org/standard/71670.html
26. ISO/IEC 29100:2011 Information technology — Security techniques — Privacy framework https://www.iso.org/standard/45123.html
27. ISO/IEC CD 27031 Information technology — Cybersecurity — Information and communication technology readiness for business continuity https://www.iso.org/standard/80975.html
28. ISO/IEC 27040:2015 Information technology — Security techniques — Storage security https://www.iso.org/standard/44404.html
29. ISO/IEC AWI TR 27024 (under development) https://www.iso.org/standard/61006.html
30. ISO 28000:2022 Security and resilience — Security management systems — Requirements https://www.iso.org/standard/79612.html
31. NIST SP 800-53 Security and Privacy Controls for Information Systems and Organizations https://csrc.nist.gov/publications/detail/sp/800-53/rev-5/final
32. NIST CSF Cybersecurity Framework https://www.nist.gov/cyberframework
33. ISO 11783 Tractors and machinery for agriculture and forestry (all parts)
34. ISO 11787:1995 (withdrawn) Machinery for agriculture and forestry — Data interchange between management computer and process computers — Data interchange syntax https://www.iso.org/standard/3247.html
35. ISO 20614:2017 Information and documentation — Data exchange protocol for interoperability and preservation https://www.iso.org/standard/68562.html
36. ISO/TC 46/SC 4 Technical interoperability https://www.iso.org/committee/48798.html
37. AgGateway: https://www.aggateway.org/GetConnected/StandardsGuidelines.aspx

A6 Public data sources

ABARES	Categories	Available dataset(s)	
Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) https://www.agriculture.gov.au/abares/data#australian-natural-resources-data-library ABARES conducts independent research focusing on Australian agriculture, fisheries and forestry. In particular, ABARES provides data collected from Australian Agricultural Census, which can be summarised at different spatial resolutions.	Agricultural commodities & trade data	• Oilseeds • Pig meat • Sheep meat • Sugar and wheat • Beef and veal • Chicken meat	• Coarse grains • Dairy • Fisheries • Horticulture • Natural fibres
	Water	• Irrigation activity dataset - Area and Water use • Murray-Darling Basin demand metadata	• Irrigation activity dataset - Production and Value
	Fisheries	• Gross value of fisheries and aquaculture production, Australia • Fisheries and aquaculture production, Australia • Wild-caught fisheries production, Australia	• Fisheries production, Commonwealth • Value and volumes of fisheries products exports • Production exports, products imports, for selected countries • Aquaculture production, Australia
	Forests	• Australian forest and wood products statistics • Australian plantation statistics • Spatial data on Australia's forests	• Forest maps and fire data • Regional forest agreement data • Data from Australia's State of the Forests Report 2018
	Land use	Highlights the purpose to which the land cover is committed. Some land uses, such as agriculture, have a characteristic land cover pattern. These usually appear in land cover classifications.	
	Productivity	Productivity measures the quantity of output produced with a given quantity of inputs. Long-term productivity growth reflects improvements in farmers' production efficiency and technological progress.	
	Farm surveys and analysis	A wide range of information (since 1940s) on the current and historical economic performance of farm business units in the rural sector. The data are used for research and analysis on a range of industry issues of concern to government and industry.	

ABS	Categories	Available dataset(s)	
Australia Bureau of Statistics (ABS) https://explore.data.abs.gov.au/ ABS is Australia's national statistical agency and an official source of independent, reliable data. Among the data available, agriculture and environment management data are most relevant to AADX.	Agriculture	• Livestock products, Australia • Agricultural commodities, Australia • Value of Agricultural Commodities Produced, Australia • Water Use on Australian Farms	• Sugarcane, experimental regional estimates using new data sources and methods • Livestock and meat, Australia • Gross Value of Irrigated Agricultural Production • Land Management and Farming in Australia
	Environment Management	• Dynamic land cover • Land use • Land use net change	• Monetary account land use • Physical accounts for land use and land cover • Land tenure

AFGC	Available dataset(s)
Australian Food and Grocery Council https://www.afgc.org.au/industry-resources/state-of-the-industry The Australian Food and Grocery Council provides an annual State of the Industry report containing data on imports and exports, business count and capital investment, regional employment, employment, AFG turnover, domestic turnover and total turnover.	Besides the data contained in the report, Australian Food and Grocery Council offers an interactive dashboard with detailed data on runover, employment, international trade and capital investment by year, category and state.

AgriFutures	Available dataset(s)
AgriFutures Australia https://agrifutures.com.au/our-industries/ Offers data and reports on a range of topics relevant to Australian agriculture and the industries that AgriFutures supports.	Contains data and resources relevant to tea tree oil, ginger, broiler emissions, bioenergy, nutrient composition of chicken and building soil carbon in the rice industry.

ARDC	Available dataset(s)
Australian Research Data Commons (ARDC) https://researchdata.edu.au/ Research Data Australia under ARDC allows people to find data for research from over 100 Australian research bodies.	Offers themed collections, data-related services and tools and open data. Of many subjects available, those that are primarily relevant to AADX are Agricultural and Veterinary Sciences, Environmental Sciences and Earth Sciences.

ASDI	Available dataset(s)
Australian Spatial Data Infrastructure (ASDI) https://www.icsm.gov.au/australian-spatial-data-infrastructure-asdi ASDI is a national framework that links users with spatial information providers. ASDI contains the necessary people, policies, and technologies to enable the use of spatially referenced data through all levels of government, the private sector, non-profit organisations and academia. Potenially useful for precision agriculture.	ASDI offers wide-ranging spatially referenced datasets that are searchable and downloadable through FIND, the Australian Government's spatial data catalogue.

ASRIS	Available dataset(s)
Australian Soil Resource Information System (ASRIS) https://www.asris.csiro.au/themes/Atlas.html Offers links to downloads, and reports, interpretations, and tables for, the Atlas of Australian Soils (CSIRO) and its digital version (Bureau of Rural Science). ASRIS provides online access to publicly available data and information on soil and land resources (including variously scaled polygon mapping, reference sites and analytical data, and interpreted national grid products).	ASRIS provides access to the Australian Soil Classification Mapping and an Atlas of Australian Soils spatial dataset. Other datasets are available to view and download here.

Australian Government	Jurisdiction	Available dataset(s)
Data.gov.au https://data.gov.au/ Data.gov.au is the central source of Australian open government data.	Federal	Anonymised public data published by federal, state and local government agencies.
Australian Government Department of Agriculture, Fisheries and Forestry https://www.agriculture.gov.au/ Provides data on Agriculture and Land, biosecurity and Trade, and Science and Research.	Federal	Provides information and links for the following categories: farming, food and drought; fisheries; forestry; animal health; and plant health.
Australian Government Department of Climate Change, Energy, the Environment and Water https://www.dcceew.gov.au/ The Department of Climate Change, Energy, the Environment and Water website covers climate change, energy, the environment, water, parks and heritage, and science and research.	Federal	• Climate change includes publications and data, Australia's National Greenhouse Accounts (emissions data), climate science and adaptation and strategies. This could be useful for regulatory compliance and sustainability. • The Energy section contains publications and data as well as policies and programs, which could be useful for regulatory compliance, research and development and incentivising renewable energy innovations. • Environmental provides information on a range of aspects including information and data, invasive species, biodiversity and waste, which could be useful for environmental compliance and sustainability metrics. • Water includes policies and resources, which can be helpful in sustainable water management and regulatory compliance. • Science and Resources offers information and data on biological resources, which can be useful for research and development and environmental conservation.
Data VIC https://www.data.vic.gov.au/about-datavic Open portal datasets released by the Victorian Government.	State of Victoria	Data about the various matters related to the environment, energy and climate change.
Department of Energy, Environment and Climate Action (DEECA) https://agriculture.vic.gov.au/	State of Victoria	Data on livestock and animals, cops and horticulture, biosecurity, climate and weather, farm management and exports.
Goulburn Murray Water (GMW) https://www.g-mwater.com.au	State of Victoria	• Datasets delivers rural water for irrigation, domestic and stock, and environmental purposes in northern Victoria. Datasets about: • Climate Change • Water for Aboriginal cultural, spiritual and economic values • Financial Sustainability

NSW Department of Primary Industries https://www.dpi.nsw.gov.au/ Works with primary producers to strengthen their industry.	State of New South Wales	Offers datasets about fishing, hunting, agriculture, animals and livestock, forestry, biosecurity and food safety and climate.
Data.NSW https://data.nsw.gov.au/ Open portal datasets released by the NSW State Government.	State of New South Wales	Offers datasets about: urban and regional planning, natural resources, industry, environment, heritage, Aboriginal and social housing, and Crown lands and water.
NSW Environmental Protection Agency (EPA) https://www.epa.nsw.gov.au/	State of New South Wales	Provides data on waste, pollution, resource recovery and more.
NSW Spatial services https://www.spatial.nsw.gov.au	State of New South Wales	Provides a secure platform to facilitate the delivery of NSW spatial datasets. The portal allows local, state, and federal agencies to deliver spatial data, asset management and visualisation services, and enables the search and discovery of datasets for all NSW citizens.
Sharing and Enabling Environmental Data NSW https://www.seed.nsw.gov.au/ Datasets about NSW environmental data.	State of New South Wales	Offers a searchable data catalogue. The most relevant categories to AADX include Biota, Environment, Climatology Meterology Atmosphere, Farming, Geoscientific Information, Inland Waters, and Imagery Basemaps Earthcover
Data WA https://data.wa.gov.au/ WA public sector data.	State of Western Australia	Datasets provides datasets on: Australian species, ecosystems, lands and the attractions in our care.
Department of water and environmental regulation https://www.wa.gov.au/organisation/department-of-water-and-environmental-regulation	State of Western Australia	Offers datasets that provide information about environment, water resources and regulations.
South Australia https://pir.sa.gov.au/ Department of primary industries and regional development	State of South Australia	Offers datasets that provide information regarding agricultural, food industries, fisheries and regional development within the state.
List data (TAS) https://www.thelist.tas.gov.au/app/content/data Data portal for Tasmanian location-based information.	State of Tasmania	Available datasets range from climate and environment, geology and soils, primary industries, and inland waters and elevation.
Queensland Open Data Portal https://www.data.qld.gov.au/ Open data released by the Queensland Government.	State of Queensland	Categories include Environment and Science, and Agriculture and Fisheries. Datasets within these categories include state of the environment, greenhouse gas emissions, biodiversity, maps and geo-spatial and monitoring data for different industries.

Northern Territory Open Data Portal https://data.nt.gov.au/ Datasets released openly by NT Government.	Northern Territory	The most relevant category to AADX would be Environment, which includes datasets on geoscientific information, farming, imagery basemaps earthcover, mineral and boundaries.

AWEX	Available dataset(s)
Australian Wool Exchange (AWEX) https://www.awex.com.au/market-information/current-statistics/ AWEX Market Information Services provides weekly, monthly and annual industry market reports for both instantaneous and historical wool market data. The information outlined in reports can be used to benchmark the Australian wool market globally.	Offers data on Market Indicator Values; AWEX Micron price guides; AWEX Eastern Market Indicators and AWEX Regional Market Indicators; as well as a Wool Statistics Yearbook detailing annual statistics for wool production; Auction Data Analysis; Area of Production Analysis; Statistics on Australian Wool Exports by Class and Destination. AWEX also offers subscription-based access to AWEX Online, with real-time Australian Wool Auction data and analysis.

BOM	Categories	Available dataset(s)	
The Bureau of Meteorology (BOM) http://www.bom.gov.au/climate/data/ BOM provides official statistics and forecasts regarding weather observations, such as rainfall, temperature, solar exposure, and various natural disasters. Given the close relationship between weather and agriculture, BOM data are expected to be valuable to DX participants.	Agriculture Services, Water and the Land (for agriculture and natural resources management)	• Rainfall • Cloud • Temperature • Wind • Pressure • Climate Influences • Humidity	• Evapotranspiration • Sunshine • Water Information • Forecasts & Observations • Climate Data Online • Our Weather & Climate
	Climate	• Long-range forecasts • News & reports • Weather station data • Data services • Maps – history to now • Temperature record	• Maps – averages • Climate change • Extremes and records • About Australian climate • Climate change
	Water information	• Water data • Water status	• Water forecast
	Environmental Information focusses on natural environment, landscapes, oceans, water, atmosphere and biodiversity	• National Plan for Environmental Information initiative • Coastal information • Atmospheric composition • Coordination	• Information infrastructure • Products and services directory • Research and collaboration • Environmental accounts

Climdex	Available dataset(s)
Climdex https://www.climdex.org/learn/indices/ The Climdex project offers a range of climate extremes indices. These indices are annual or monthly statistics of modelled or observed climate data. This data could be useful for yield predictions, crop protections and crop planning.	• Number of frost days; summer days; icing days; tropical nights. • Growing season length. • Maximum value of daily maximum temperature; maximum value of daily minimum temperature; minimum value of daily maximum temperature; minimum value of daily minimum temperature; daily temperature range; extreme temperature range; cooling degree days; growing degree days; heating degree days; mean daily mean temperature; mean daily maximum temperature; mean daily minimum temperature; simple precipitation intensity index; maximum length of dry spell: maximum number of consecutive days with RR < 1mm; maximum length of wet spell: maximum number of consecutive days with RR ≥ 1mm; contribution to total precipitation from very wet days; contribution to total precipitation from extremely wet days; annual total precipitation on wet days.

CSIRO	Categories	Available dataset(s)
Commonwealth scientific and industrial research organisation (CSIRO) https://data.csiro.au/ The CSIRO Data Access Portal provides public access to research data published by CSIRO. The datasets within the category Agricultural, Veterinary and Food Sciences are most relevant to AADX.	Agricultural, Veterinary and Food Sciences	The datasets were further classified into different domains such as Agricultural Spatial Analysis and Modelling, Crop and Pasture Nutrition, Food Chemistry and Food Sensory Science, Horticultural Crop Protection etc.

CSIRO	Available dataset(s)
CSIRO National Soil Site Database https://data.csiro.au/collection/csiro%3A7526v7 Presently contains over 21, 000 descriptions of soil site investigations since 1948. The database and the Australian National Soil Archive provide the foundation for the development of a national soil spectral library and offer a federated collation of available soil databases.	Offers datasets from CSIRO-managed research and field stations, as well as national collaborations including the Northern Australia Water Resource Assessment (NAWRA). Data come from CSIRO Land and Water, CSIRO Ecosystems Science, Department of Agriculture and Food (Western Australia), Department of Land Resource Management (Northern Territory) and Department of Primary Industries, Parks, Water and Environment (Tasmania)

DEA	Available dataset(s)
Digital Earth Australia https://www.dea.ga.gov.au/products Digital Earth Australia (DEA) uses spatial data and images recorded by satellites to detect physical changes across Australia.	DEA provides data in five major categories: • baseline satellite data, • land and vegetation (including land cover, fractional cover, mangroves, wetlands, and surface reflectance), • inland water (including water observations and waterbodies), • sea, ocean and coast (including intertidal elevation, extents and tide imagery), and • hazards (bushfire monitoring).

Earth Engine Data Catalogue	Available dataset(s)
Earth Engine Data Catalogue https://developers.google.com/earth-engine/datasets/ Earth Engine includes historical imagery and scientific datasets for Earth science analysis. Among these, the climate and weather data, satellite images and geophysical data would be valuable additions to AADX.	Some highly relevant datasets that are available include surface temperature, climate, atmospheric, weather, Landsat satellites image, weather radar images, ocean and land data, high-resolution imagery, land cover maps and cropland data.

EAtlas	Available dataset(s)
EAtlas https://eatlas.org.au/ Provides environmental research, maps and data for tropical Australia. This could be useful for environmental monitoring and sustainability metrics as well as regulatory compliance.	EAtlas provides a data catalogue (repository listing) and advanced metadata search function. Some of the datasets that may be relevant to an agricultural DX are: • Commercial Line, Net and Trawl Fisheries Active Licenses, Effort days, Harvest Weight and GVP - 2013 (DAFF, SELTMP) • Vegetation Mapping of the Wet Tropics Bioregion 2008 • Repeat gully terrestrial laser scanners data for geomorphic change detection and estimating volumes of erosion and deposition - Upper Burdekin and Bowen catchments 2016 - 2019

FRDC	Available dataset(s)
Fisheries Research and Development Corporation (FRDC) https://www.frdc.com.au/seafood-production-and-trade-databases FRDC offers market data on the gross value of Australian seafood production, including data on Australian seafood data by value and volume, including imports and exports and species-specific data.	Databases include Abalone exports, Prawns imports and exports, Rock Lobster exports, Seafood import and export by Volume by Species, Food and Agriculture Organization Capture Production, Gross Value Production, Seafood import and export by Commodity, Seafood import and export by Species with AUD exchange rate and Seafood import and export by volume.

Geofabric	Available dataset(s)
Australian Hydrological Geospatial Fabric (Geofabric) https://datasets.seed.nsw.gov.au Geofabric is a specialised Geographic Information System (GIS) that details the spatial relationships of important hydrological features such as rivers, lakes, reservoirs, dams, canals and catchments. By detailing the spatial dimensions of these features, models can be developed to show how water is stored, transported, and used through the landscape. This data may be of interest for assessing sustainability and demonstrating compliance.	• Hydrology Cartography • Hydrology Network • Hydrology Catchments • Hydrology Reporting Catchments • Hydrology Reporting Regions • Groundwater Hydrology

Geoscience Australia	Available dataset(s)
Geoscience Australia https://www.ga.gov.au/scientific-topics/national-location-information/dataspatial-applications Geoscience Australia's Interactive Maps is a discovery and exploration view of Geoscience Australia's geo-spatial data products and web services. It provides access to the wealth of curated information content organised into scientific disciplines and decision support themes, linked to related information. Data is portrayed as dynamic maps, links to metadata, map printing and access to OGC (Open Geospatial Consortium) web services. Some maps have additional tools providing specific functionality.	Interactive maps offers the following data categories: Australian Marine Spatial Information System; Earth Observation and Satellite Imagery; National Location Information; Geology and Geophysics; Hazards; Marine and Coastal; and Water.

GRDC	Categories	Available dataset(s)	
Australian Government Grains Research and Development (GRDC) https://grdc.com.au/ GRDC provides research reports, publications and data on grain production, agronomy, pest management and technology adoption.	Agricultural and Veterinary Sciences	• Agriculture, land and farm management • Animal production • Crop and pasture production • Fisheries sciences	• Forestry Sciences • Horticultural production • Veterinary sciences • Other agricultural and veterinary sciences
	Environmental Sciences	• Ecological applications • Environmental science and management	• Soil sciences • Other environmental sciences
	Earth Sciences	• Atmospheric sciences • Geochemistry • Geology • Geophysics	• Oceanography • Physical Geography and Environmental Geoscience • Other Earth Sciences • Physical Geography and Environmental Geoscience

Hort Innovation	Available dataset(s)
Hort Innovation https://www.horticulture.com.aWu/ Hort Innovation provides an annual Australian Horticulture Statistics Handbook with the most comprehensive and current data available across the Australian horticulture sector, including international trade statistics.	Offers information, insights, annual reports and data on Australian horticultural products, as well as access to product specific levy fund grower pages.

IMOS	Available dataset(s)
Integrated Marine Observing System (IMOS) https://imos.org.au/data IMOS offers the Australian Ocean Data Network (AODN), a Data Facility whose aim is to facilitate research by offering quality-controlled data that is discoverable, accessible, downloadable, usable and reusable. IMOS also offer data tools to ensure specialised data is more accessible. This could be useful for research and development purposes.	The IMOS offers the Integrated Marine Observing System with up-to-date information on surface currents and temperature for Australian oceans.

MLA	Available dataset(s)
Meat & Livestock Australia (MLA) http://statistics.mla.com.au/Report/List MLA's Statistics database contains data on pricing, production, and trade regarding livestock from Australia and around the world.	Data categories include By-products, Economic data, Farm data – General, Feedlot data, Herd and Inventory data, Livestock Prices, Meat Prices, Production and Supply and Trade data. These can be further classified into a range of values and sorted by region/country and reporting period.

National Map	Available dataset(s)
National Map https://nationalmap.gov.au/ Provides the NationalMap, a visualisation tool for open data from Australian Government agencies, facilitating geo-spatial data exploration and use. Potentially useful for environmental conservation and sustainability, as well as research and development.	Available datasets relevant to the AADX include Agriculture (Catchment Scale Land Use), Climate, Environment, Habitation, Land Cover and Land Use, Satellite Images (Baseline data and Land and Vegetation) and Water (Ground Water, Surface Water, Hydrogeology and Water Regulations Data).

NCI	Available dataset(s)
National Computational Infrastructure (NCI) https://nci.org.au/our-services/data-collections-management NCI manages nationally significant datasets registered in the National Research Data Repository, such as international climate modelling datasets and time-series satellite imagery for the Australasian region and globally. This FAIR data is intended for research and informs a range of applications, technologies, and services. Their datasets could be useful for research and development purposes, including collaborations and environmental conservation.	The NCI data catalogue includes: • Climate, meteorology and atmosphere • Oceans • Imagery base maps earth cover • Geoscientific information • Biota • Health • Environment • Elevation Inland waters

OFT Datasets	Available dataset(s)
Online Farm Trials (OFT) https://www.farmtrials.com.au/ As a collaboration between Grains Research and Development Corporation (GRDC) and Centre for eResearch and Digital Innovation, OFT provides open and free access to on-farm, or field-based, cropping research trial data and information. Since this platform provides field-based data, it is expected to be valuable to AADX participants.	The database contains data on various crops such as cereal, pulse, oilseed, forage, etc.

OzFlux	Available dataset(s)
OzFlux https://www.ozflux.org.au/ OzFlux is an ecosystem research network set up to provide ecosystem modelling communities with consistent observations of energy, carbon and water exchange between the atmosphere and key Australian and New Zealand ecosystems. It forms part of a 500+ strong international network aimed at monitoring the state of ecosystems across the globe through continuous, long-term micrometeorological measurements. This data may be of interest for research and monitoring purposes, including collaboration and environmental conservation.	The Ozflux Data Portal provides data from their network of flux towers, organised into collections and viewable using a map or list view. It provides a search function and a resources menu for metadata information.

Rural Bank	Available dataset(s)
Rural Bank https://www.ruralbank.com.au/ Provides monthly commentary on production and pricing trends for Australian agriculture that serves as both an overview of current trends and an outlook for the near future.	Offers analyses of production and pricing trends for Australian horticulture producers, cattle producers, broad acre farmers, sheep producers, wool producers, and dairy producers. It also offers data on Australian farmland values, agricultural outlooks, and agricultural trade.

SEED	Available dataset(s)
The Central Resource for Sharing and Enabling Environmental Data in NSW (SEED) https://datasets.seed.nsw.gov.au/dataset/australian-soil-classification-asc-soil-type-map-of-nsweaa10 Datasets about NSW environmental data.	SEED provides the Australian Soil Classification (ASC) soil type map of NSW, identifying the dominant soil types across NSW and incorporates 55 different datasets of varying scales across the state. They also offer the SEED map, including other natural resource databases such as vegetation.

SILO	Available dataset(s)
Scientific Information for Landowners (SILO) https://www.longpaddock.qld.gov.au/silo/ SILO, hosted by the Queensland Department of Environment and Science (DES), is a database of long-term Australian climate data. The daily meteorological datasets for a range of climate variables are excellent sources of data for analysis. SILO also provides spatially gridded data that were constructed from mathematical interpolation techniques.	SILO provides both Point Data and Gridded Data. The former are continuous daily time-series data at recording stations or grid cell locations. Gridded data are daily climate surfaces which have been derived by interpolating observed data across the area.

SLGA Datasets	Available dataset(s)
Soil and Landscape Grid of Australia (SLGA) https://esoil.io/TERNLandscapes/Public/Pages/SLGA/ SLGA provides freely available data about soil and landscape attributes within Australia, which are considered important aspects in agriculture.	SLGA datasets contain information on soil attributes, landscape attributes, modelled soil attributes, sensor measurements, depth layers and spatial characteristics.

Soil Science Australia	Available dataset(s)
Soil Science Australia https://www.soilscienceaustralia.org.au/about/about-soil/soils-data-maps-and-information-sources/ Soil Science Australia is a not-for-profit professional incorporated association for soil scientists and people interested in responsibly managing Australia's soil resources and the national soil science body.	Provides links to soil data, maps, and information sources from national and state/territory levels and also from the CSIRO.

Wine Australia	Available dataset(s)
Australian Wine and Grape Authority (Wine Australia) https://www.wineaustralia.com/ Wine Australia provides Market Bulletin, which features analysis of the global wine market and country-specific categories for exploring wine production, consumption and more. It also offers Market Insights, with a range of data and analyses relevant to the global wine market.	Wine Australia offers datasets categorised by users including Wine Exporters, for Winegrape Growers, for Winemakers, and for Students and Industry Commentators.

Wool	Available dataset(s)
Australian Wool Innovation Limited https://www.wool.com/ Australian Wool Innovation Limited provides weekly price reports, monthly market reports, wool production forecasts and the WoolQ ™, a platform offering digital tools to wool growers, brokers, classers and buyers at all stages of the wool production cycle. The platform includes Ready Reckoner, for wool clip price estimation.	Offers market intelligence data and data on sheep numbers by state, and runs a survey on sheep producer intentions.

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