#LETSDOTHISTOGETHER

DATA SHARING TO ACHIEVE DATA INTEROPERABILITY

NUFFIELD
NEW ZEALAND
FARMING SCHOLARSHIPS

Global vision, leadership and innovation

2022

Lucie Douma

Nuffield Scholar

I wish to thank the below Investing Partners for their support over my scholarship period and beyond

NZRLT Partners

Strategic Partners

AGMARDT FUTURE SHAPERS

beef+lamb new zealand

DairyNZ

FMG Advice & Insurance

Mackenzie Charitable Foundation

Programme Partners

FAR

Farmlands co-operative

Horticulture New Zealand

LIC

Ministry for Primary Industries Manatū Ahu Matua

Rabobank

TIAA Global Asset Management

Zespri Kiwifruit

Service Partners

AgriHQ

pwc

NZ Farm Life Media Down to Earth

Tavendale and Partners

Primary Purpose

Federated Farmers of New Zealand (Inc)

Scholar Contact Details
Name: Lucie Douma
Phone: +64 27 696 3973
Email: lucie.douma@gmail.com

In submitting this report, the Scholar has agreed to Nuffield New Zealand publishing this material in its edited form.

Nuffield New Zealand
PO Box 85084
Lincoln 7647
Nuffield@ruralleaders.co.nz
+64 21 1396 881

Table of Contents

Acknowledgements

I am hugely grateful for the experience of being a Nuffield Scholar. Thank you to everyone who tested my thinking and helped me grow by challenging me. The hospitality and generosity of time that I have been shown will never be forgotten.

Firstly, thank you to Rural leaders New Zealand for selecting me as a scholar and believing in me and my topic. The team from Rural Leaders New Zealand has been outstanding in their support and advice. Special thanks to Lisa Rogers, Chris Parsons and Hamish Gow who helped with contacts and support throughout the year.

I want to thank all the people who spent significant amounts of time with me over video calls, in person meetings and follow-up conversations, these people number into the hundreds so I will not name everyone individually. Every conversation I had helped me in my thinking and this report would not have been possible without the support of many people who generously offered their time to mentor me, discuss, review, and brainstorm ways to address data interoperability on farm.

This report is not a solo effort but the amalgamation of many ideas and considerations. I met with a number of people across the United Kingdom, Norway, The Netherlands, The United States of America, Canada, Australia, and New Zealand who offered advice, support and hospitality. Without this these ideas would not have come to fruition and I am immensely thankful to everyone who has helped me along the way.

I also want to thank the Ministry for Primary Industries which supported me by enabling me to take time off to travel overseas and meet with all the people above. I had almost four months overseas so this is not a small ask of an employer, and I am immensely grateful to my team who helped keep everything running smoothly while I was away.

I also want to thank my family who constantly had to hear about my thinking and ideas from the conversations I had, they were as much a part of the journey as me.

Lastly I want to thank my Nuffield scholar group of 2022 with all the new friends I made overseas as well as my New Zealand co-scholars Parmindar Singh and Anthony Taueki, you have been a fantastic group to share this experience with.

Executive Summary

New Zealand is a country of entrepreneurs and leaders in the creation of new systems and apps that can capture on farm data. A significant opportunity to automate data collection to match the systems together and see the data holistically still remains. Each company is creative and innovative in their own right, but farmers and growers want to see the data consolidated. This is how they can make robust, science based decisions on farm.

This is becoming increasingly important as we move into a digital world where information is accessible at consumers' fingertips – we need farm data to be in this same realm. With the new generation coming through, it is no longer enough to have values and show what farmers stand for, we also need to prove it.

During my Nuffield year I spent four months overseas visiting different agriculture companies, farmers and governments. I came back with a strong understanding of the risks of not integrating our data. Covid-19 has changed our world faster than ever before. There are new standards and requirements to be met that are being imposed by consumers. No longer can we afford to look at siloed data systems.

We should not be afraid of transparency because the world is demanding it. Our consumers are demanding it. If we do not do it the effect will be that we will be told how to farm because we haven't proved we are better than 10 years ago. I believe we do farm better. But belief does not cut it anymore. For the next generation coming through we need the data and the evidence of our farms to back up our claims.

No country or system I came across has a fully integrated farm data system. In New Zealand we are well placed to try something new around data interoperability because many of our companies are co-operatives and farmer owned. We are in the premium space and need to hold our premium position. We also need to have all the information available to make the best decisions on farm and enable scenario planning and modelling. We should be able to answer questions such as:

- What happens if I put 40 kilograms less fertiliser on per hectare? What does that do to my beef production and revenue line?
- What happens if I invest in cow monitoring technology and then catch mastitis and disease earlier? What does this do to production and revenue?

Consider the emerging discipline of a farm data manager. The farm data manager will work directly with farmers and growers to determine their drivers for farming and to create a data strategy. Every farmer and grower has different needs, drivers, and reasons for being. Different data points interest different farmers. Each farm and farmer or grower requires a solution that matches their driver and strategy.

Farmers and growers need a bespoke solution for them – a data manager can assist with this. It is not practicable for every farm to employ a data manager. Instead, a data manager will have a portfolio of farmers and growers they work with to give them a solution that best works for them. We need to try something different to move forward on on farm data interoperability. This report proposes establishing a new discipline of the farm data manager. Farmers and growers are not expected to be finance experts instead they outsource this to an accountant to support them. So why are we asking them to be data experts? Instead a farm data manager can support them.

Personal story

Thirty years ago my family were dairy farmers in Friesland, the Netherlands. At the time my parents were pioneers in technology adoption and embarked on a journey to automate the indoor dairy systems to identify individual feed and production statistics for each cow in the herd. At the time there were three systems on the market to choose from. Each branded system required them to stay with one brand for all their farm system requirements because data could not be shared amongst systems and matched to different brands. There was one software company on the market that enabled sharing of data, but this came with a significant number of challenges from the hardware companies.

Fast forward thirty years and we are in the same position. Data sharing amongst systems to create interoperability is not common-place in the agriculture sector. My Nuffield travels have shown me this is the case globally. Innovative farmers and companies are trying to address data interoperability through their own means, but large dominant agricultural supply companies have not made it easy. They are not always working on behalf of the farmer or grower. This has created data silos within farm systems and forced farmers and growers to use either paper or excel tools to match different data sets and understand what is taking place on the farm holistically.

When setting out on my Nuffield journey my goal was to find a different way forward that gives ownership back to the farmer or grower to understand their farm system as a whole, with data that connects across the farm. This report outlines a different way of thinking about the problem and identifies a potential way forward. This may not work for everyone but we need to try something different so #letsdothistogether and be farm pioneers in digital tools again.

Introduction

Traveling in a post Covid-19 world has opened my mind to what is happening. There is a new normal. A lot has changed in two years of isolation. Consumers have suddenly become farmers and are telling food producers what they can and cannot do. Values based eating is dominating nutritional requirements. Generation Z is coming through to adulthood and they do not just live by values – they need proof.

We can no longer do what we used to do and we need to step up and meet this new requirement. So what does this mean for farmers and growers? We need data to back up our stories and to prove we are living by our stated values.

We live in a world where it is becoming increasingly important to provide transparency on the activities within farms. Consumers want information, customers want to know what the processes are so they can start to capture their scope three [1] emissions within their own value chains, and farmers need to know what is happening on their farm so they can optimise the management and inputs into the farm. The common thread through these goals is data.

Data is king and it is critical to find a way to capture, manage and share data seamlessly. The focus of this report is on data sharing between systems, and it will touch on collection and management of data as they are steps in the process to enable data sharing between systems.

Farmers around the world are increasingly being asked to track data and information on farm. This is coinciding with access to greater levels of technology on farm. In theory, the sensors, apps, farm management software and machinery should be able to give a holistic view of on-farm activities, impacts and outcomes. In practice, there is one big flaw – each of these pieces of technology use their own software and databases which means farmers cannot see them in conjunction with each other and create true insights.

New Zealand farmers are facing this same challenge. New Zealand's products are at the premium end of the market which means New Zealand needs to lead this space to maintain our premium status.

[1] Scope one and two emissions are those inputs and energy requirements that a company has direct control over. Scope three emissions are indirect emissions, including those within the supply chain, that are not owned or controlled by the company.

The problem is universal. I have spoken to too many farmers that showed me their excel spreadsheet they use to manually collate various data sets together to enable a full understanding of the farm. Not only is this a huge waste of time as data points have to be manually pulled across it is also prone to human error.

While on my Nuffield travels I was around a board table at a large grain grower in Saskatchewan, Canada, and their leadership team showed me the excel spreadsheet they use to combine six systems including machinery data, grain inventory management, staff management, and farm inputs among others. The growers were happy with the systems they were using because they were powerful in their own right, but how much opportunity is wasted by not combining the systems automatically? They explained it takes one full-time employee over the course of a year to map the systems manually and get a holistic view of the grain operation.

This data challenge has gained global prominence where it has formed part of the UN Sustainable Development Goals.

The farming social license to operate is increasingly coming under pressure, alongside a growing requirement to report on farm activities. In parallel to this there is a global movement where non-farming communities are putting greater pressure on farming communities to dictate how to operate – only this is happening with little to no understanding of the current farming practices. Evidence is required to back-up stories and claims on farm. Data interoperability serves the dual purpose of better management of farms, and responding to the growing rhetoric of farm practices. A new way forward on data interoperability needs to be considered to give farmers and growers the results they need. It is time to take matters back into farmers hands.

How to read this report

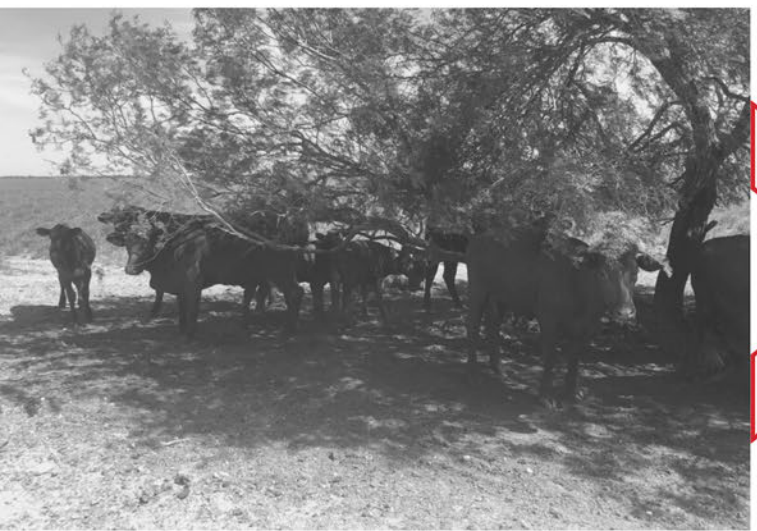
This report serves a number of different audiences with different interests and experience in data interoperability.

For **farmers and growers** who want to know why this is important and how this could work, the relevant sections are: **Section one and five.**

For **agriculture support companies** and consultants who want a bit more detail and want examples of how different techniques have been employed, the relevant sections are: **Section one, four and five.**

For those with a stronger **understanding of data interoperability** and the challenges involved in it, and have experience in technology spaces, the relevant sections are: **Section one, two, three, four, and five.**

	Farmer/ grower	Agriculture company	Consultant	Government	Data/ technology provider
Section one: The reason why					
Section two: The problem and therory					
Section three: On-farm data maturity					
Section four: Case studies					
Section five: An alternative way forward					



#LETSDOTHISTOGETHER

Section one

The reason why

Why data interoperability on farm is required

A farm is part of an eco-system and value chain, it provides a product for end consumers. A farm does not exist in isolation - with no end consumer there will be no products to create. It is important for farmers and growers to step beyond the farm gate and consider what the end consumer wants and what their demands are.

Generation Z (Gen Z) is the emerging consumer. McKinsey and Company (2022) loosely describes members of Gen Z as people born between 1995 and 2010. In New Zealand, Gen Z now makes up 21% of the population. A Mckinsey and Company (2022) survey found that their behaviour is anchored around one element – the search for truth. There is a strong drive for authenticity. This group pays a premium for products that align to their causes and ethics – and they want the proof that claims are acted upon.

Farmers and growers do not traditionally sell direct to consumers, so what does this mean for farmers? New Zealand farmers and growers are at the premium end of the market. In New Zealand, farmers cannot compete on scale or price with the rest of the world. The emphasis is on quality where a better product needs to be sold to gain access to different markets. To enable this farms need to be transparent. Farmers and growers need to share what they are doing and what impact they are having. This is not a trend that can be ignored. Some interesting facts that Voyado Lund (2022) found about Gen Z shopping habits are:

- 77% have taken some form of action for a cause they believe in.
- 23% have boycotted a brand.
- 65% have purchased something based on an influencer's recommendations.

Farmers and growers need to have data and evidence to align themselves to the Gen Z population. One New Zealand company that is doing this well is The New Zealand Merino Company (NZM) who launched ZQRX in 2020.

ZQRX is a regenerative wool platform. NZM has recognised that consumers pay more for products that align to their beliefs and ethics, it also understands that consumers need proof of the claims being made. With ZQRX farmers are measured against a set of sustainability indicators covering human, animal and environmental areas. This framework provides a farmer the baseline of where they currently measure, the information to monitor progress, and in time, the customised models to inform their decision-making on farm. The intent is that farmers are on a continuous improvement journey, being the best stewards for the land they can be. NZM has found a way for farmers to engage with consumers.

The key to this is data. NZM and the farmers themselves need data to be able to track their progress against the criteria.

Data interoperability is crucial for farmers to maximise farm performance, and for farmers to prove they are 'walking the talk'. Data is required to be able to meet consumer demands and remain in the premium space because it enables decisions to be made and stories created. With an emerging Gen Z population siloed data systems can no longer be the norm.

Figure one, Background ZQRX spider diagram taken from www.discoverzq.com/zqrx

Section two

The problem and theory

UN Sustainable Development Goals - Data

The Unite Nations (UN) has 17 Sustainable Development Goals (SDGs) as shown in figure two. These goals need to be measurable with data attached to them. Each country has different methods and tools for collecting, assessing, and measuring the criteria for the SDGs. The UN has a difficult time to pull the data together to see how the global holistic progress towards each goal is tracking. Currently, the world is off-track to achieve the SDGs, and a lack of investment in data. Across the 17 SDGs, comprehensive quality data exists for just six goals in most countries.

The UN has identified that data is critical in the SDGs and has created a global partnership for sustainable development data with the tagline:

"Better Data. Better Decisions. Better Lives."

Better data means more information is available and can lead to better decisions. These decisions are based on evidence and therefore provide better lives for those involved. This is critical to achieve the SDGs - but there is a piece missing.

Data alone is not enough, there is also a requirement for 'better connections' to connect data sets together and enable a holistic understanding. It is about interpersonal connections, relationships and trust to enable data sharing between people. A suggested tagline is:

"Better Data. Better Connections. *Better Decisions. Better Lives."*

These same principles can be applied to agricultural data.

Figure two, UN SDGs

#LETSDOTHISTOGETHER

A fair data future

The United Nations is promoting a fair data future for data use and sharing with the right people. They have developed a Data Values Manifesto with the following outcome:

"The Data Values campaign is a global movement to challenge power structures in data to ensure that we all share in the benefits from its collection and use. The #DataValues **Manifesto calls for change** in how we **design, collect, fund, manage, and use data. Organizations, governments, and people must act now and together to create this change.**" *(Global Partnership for Sustainable Development Data, 2022)*

These same requirements apply to enable data interoperability with New Zealand's agricultural data. Government, agricultural companies, and farmers need to work together to progress our data maturity. #Letsdothistogether

Government – needs to create an enabling environment and support the development of external data sharing APIs

Agricultural companies – need to advance their systems and develop external data sharing APIs and share data back with the farmers and growers that is in an accessible format.

Farmers and growers – need to take control and accountability of their own data to progress their farming operations. A farm does not sit in isolation and cannot be treated that way.

What is an API?

An API is an Application Programming Interface which enables two software components to communicate with each other using a set of definitions and protocols.

An API is like a menu in a restaurant where the menu is a list of dishes with a description of it. When the customer orders, the kitchen does the work and provides the finished dish. The customer does not know exactly how the kitchen prepares the food and they do not need to know as long as they can trust the quality of it.

APIs are also used broadly in phone apps. An example is a weather app, the app does not have a weather station linked to it. Instead, it uses an API to pull data from the weather station and then presents this to the stakeholder in the form of an app, generally alongside other information like temperature and precipitation. An API is key to accessing this data.

The same principle applies to agriculture data – the software developer does not need to know exactly how something is collected they just need to know what is collected and the definition that has been used.

Data ecosystems

Data ecosystems are important to be able to provide longevity and enable innovation within data sets.

At a global level the UN has partnered with the World Bank to drive investment into data ecosystems to help achieve the SDGs. Together they have created an investment case for countries to invest in more and better data using the *"Data with Purpose" (Unlocking Impact: Data with purpose 2022)* campaign. The investment case outlines the benefits of investing in tools and systems for better data and the actions stakeholders need to take across various sectors.

Smart data investments can generate significant returns for societies, ecosystems, economies, and communities. In its 77th Assembly held in 2022, the UN identified five impact opportunities for data, these have been adapted to identify what the farm opportunity could be:

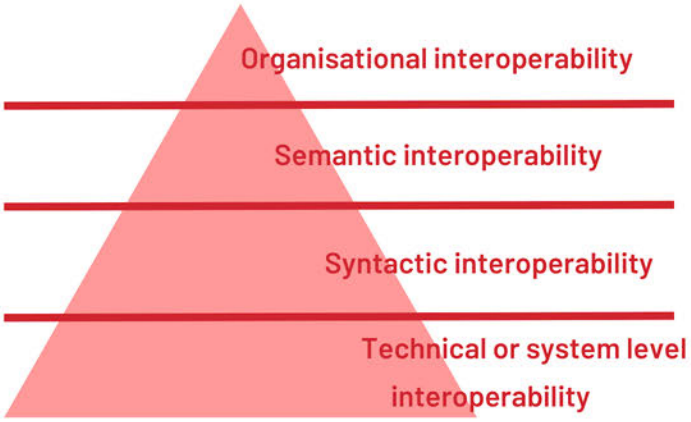
Building data ecosystems for global impact

Impact opportunity - UN identified	Impact opportunity - farming
Data-driven anticipatory action ensures crisis responses are earlier, faster, more targeted, and dignified.	Data-driven actions on farm can mitigate risks such as identify sick animals through vital signs prior to visual observation, meaning a quicker more targeted response can be taken to enable quicker recovery.
Combining and repurposing data from different sources deepens SDG impact.	Combining on farm data systems enables a holistic view of the farm to enable scenario planning of different practices and what the outcomes would be.
Public data improves service delivery, targeting, accountability, and empowerment.	Public data can be viewed alongside farm data to benchmark the farm across sectors and countries – enabling global comparisons of operations and activities.
Private sector data can fuel growth and boost development.	Access and analysis of private sector data from farm suppliers can enable maximisation of productivity and profitability on farm.
Improving data infrastructure helps ensure equitable access to services.	Improving data infrastructure means time can be spent analysing the results rather than inputting and connecting the data.

Table one: Adapted from Concept note - High-Level Event on Unlocking Impact: Data with Purpose, 2022

What is data interoperability?

From the literature there are four agreed levels to data interoperability. Different authors have ordered them based on their perceptions of importance. I relate closest to how it has been described in the health sector by Lehne et al. (2019) as:



The UN has defined data interoperability as:

"The ability to access and process data from multiple sources without losing meaning and then integrate that data for mapping, visualisations, and other forms of representation and analysis. Interoperability enables people to find, explore, and understand the structure and content of datasets.

In essence, it is the ability to 'join-up' data from different sources to help create a contextual and holistic picture for simpler (sometimes automated) analysis, better decision-making, and greater accountability." *(Global Partnership for Sustainable Development Data, 2022)*

01 Organisational interoperability

This is one of the most important aspects to interoperability. At the highest level, interoperability needs to involve organisations, legislation, and policies - this is the human relationship part of data interoperability. Exchanging data across systems is not the end, ultimately, it should help the user work more efficiently and productively. This is the hardest one to achieve as it requires common business workflows and processes to enable sharing across the sector. Different stakeholders have different interests (and they do not always aim to maximise interoperability). Policies and incentives are required for interoperable data exchange, sometimes this is in the form of financial gain and in other cases data interoperability can be enforced through legal regulations.

02 Semantic interoperability

This type of interoperability allows the data to be interpreted correctly because it is in the same language using the same definitions. Here the data within the files is the same and data defintions is critical at this level of interoperability. Using a USB as an example, if the document contained within the USB can be opened, then the reading of the data needs to use the same terms and definitions. Semantic interoperability is the domain of terminologies, nomenclatures, and ontologies – i.e. data definitions and standards. This common language needs to be understandable to humans and machines worldwide. Data standards here can provide data that has a clear structure and unambiguous semantics - this enables the achievement of true interoperability.

03 Syntactic interoperability

Data-level or syntactic interoperability enables data to be shared across applications and platforms. Here the format and structure of the data needs to be the same. To carry on with our example of the USB stick - the computer needs to be able to open the files contained within the USB stick so a Microsoft Word document can be opened by the computer if the computer has Microsoft Word installed, and the USB has the document file .doc - the same language needs to be used.

04 Technical or system level interoperability

This is the base level of interoperability and describes the technical elements that are required. An example would be moving data from a USB stick to the computer - in this case the computer needs to recognise the USB stick as a device. This requires communication channels and protocols for data transmission between the two devices. With our modern digital networks achieving this level of interoperability is straightforward. However, moving data between systems is not enough. Syntactic and semantic interoperability are required to make sense of the data and to process it to get meaningful information.

Challenges to achieving data interoperability

The research into interoperability challenges for farm systems has consistently raised four key challenges (Henriyadi, 2021; and Zeng, M.L., 2019):

Data interoperability challenge	Definition of challenge	Potential solution
Heterogeneities of the schema	Differences in the reference frameworks and data source	To overcome schema heterogeneities ontology matching can be used to identify the semantic relation between two objects so they are connected
Granularity of data	Is related to how the data is presented	Data granularity can be overcome through data integration or data warehousing
Mismatch entity naming and data unit	Differences in the naming or data unit for the same thing	Ontology mapping is a method used to overcome the mismatch with entity naming and data unit issues. An ontology map describes the data structure transformation process from one schema into a different schema by transposing the data.
Inconsistency of data	Data that comes from several external data sources provide a different value for the same thing	To overcome this challenge the best external data source should be selected for use.

Table two: Data interoperability challenges amalgamated from Henriyadi, 2021; and Zeng, M.L., 2019

Schematic transposition is important for the data to be put through processing so it can be seen in conjunction with other data. This is a similar process the brain goes through to make sense of the outside world as shown in figure three.

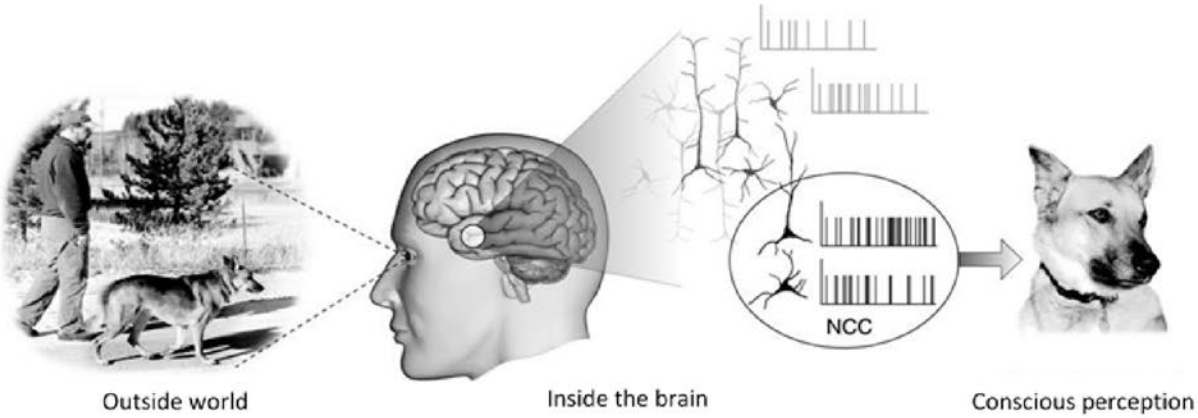


Figure three, Process brain goes through to convert visual senses (Lizardo, 2021)

Farm data is transposed through a system to provide information on farm. The challenges that have been identified can all be worked on at a technical level and a solution identified. The biggest hurdle in data interoperability remains in the relationships, competitive nature, and data ownership of the companies involved in servicing the agriculture sector.

Wisconsin farming landscape, author's photo

Achieving data interoperability

Javaid (2022) has identified three steps to achieving data interoperability as:

Step One

Data-level interoperability can be achieved through data integration platforms such as data warehouses and data lakes. These centralised repositories of data enable data to be collected from different sources, stored in a single unified location, organised, and accessed in various formats.

This is necessary because it enables systems to adopt common data formats and structural protocols. The data can be accessed and applied to various machine learning and analytics tools to gain information and insights.

Step Two

This step helps to achieve semantic-level interoperability by adding information about the data (metadata) and connecting each data element to a standardised, common vocabulary. This process involves annotating and labelling the data.

This is the step where data standards are used to ensure that data from multiple sources can be accessed and interpreted correctly by different systems. It helps organisations create uniform datasets that are consistent across various data sources.

Step Three

The third step is where the data vocabulary needs to be established and linked to an ontology. To link a vocabulary to an ontology, two approaches can be used:

Data mapping
Involves connecting data elements from different formats into one unified data structure.

Data federation
Is a technique that allows data stored in multiple data sources to be shared and accessed as if it were stored in a single data source.

The outcome

When data interoperability is achieved it enables the sharing of useful information in a timely manner.

An example of achieving this from the health sector is the data from a patient who had a blood test last week at his doctor's office can be used during a trip to the emergency room today, saving the time and cost of doing more (and unneeded tests) at the hospital. This is because the data is attributed to the person and can be shared across platforms.

On-farm it means that all data seamlessly integrates and farmers and growers can start to attribute fertiliser use with weather patterns to production and financial metrics. If information can automatically connect on farm then farmers and growers have the power to start scenario planning and modelling what the impacts could be under different scenarios.

Data definitions to create clean data and structured data sets

To create data interoperability Noura et al. (2018) has identified what is required in figure four.

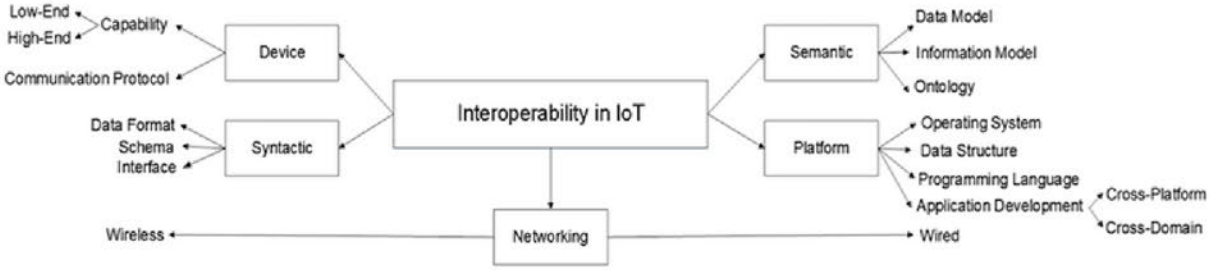


Figure four, Requirements for data interoperability on the internet (Noura et al., 2018)

Clean data and clear data definitions are critical to achieving data interoperability. Data standards have been considered as a way of achieving data interoperability, however, there are a number of global data standards that are used in agriculture. Most are voluntary which leads to the creation of more data standards that are 'better than before'. We need to make sure that with agricultural data standards we do not reinvent the wheel. This is very clearly highlighted in a comic strip figure five.

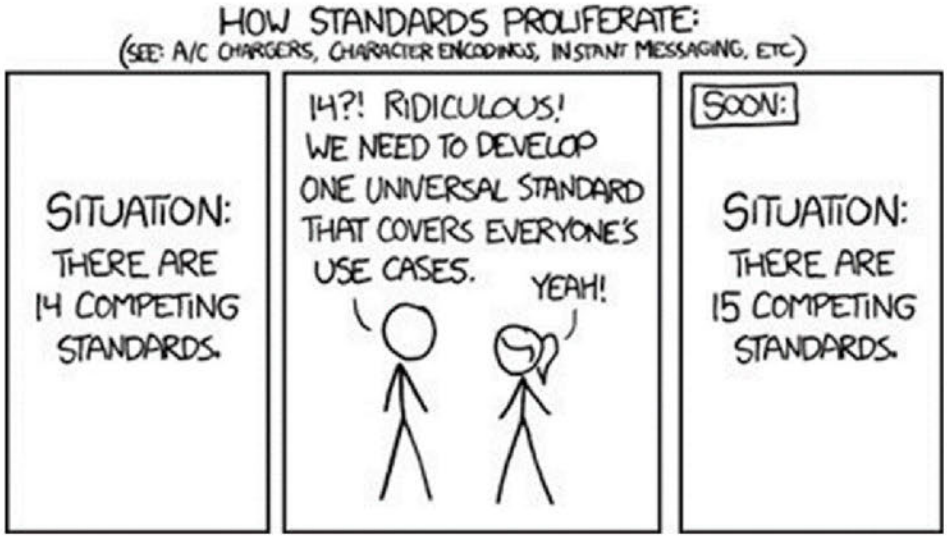


Figure five, Comic strip taken from Standards and data exchange in Agriculture (2021)

Rather than using the same data standards it is more important that companies have clear data definitions. This enables an API to pull the data from one system into a data lake, then a transformation on the data can occur to make it compatible with other data and enable amalgamation. This requires technical expertise and we cannot expect farmers and growers to reach this level. Rather, this is a discipline in its own right.

Global leader views

I had the great privilege of meeting with Dr Andres Ferreyra, who is Convener of a Special Advisory Group on Smart Farming that is developing an ISO standard for Smart Farming. He is working with a number of data standards already in the market to create an overarching ISO standard.

Dr Ferreyra highlighted that there are a number of angles in play at the moment with data interoperability. The key requirement is that there needs to be a return on investment (RoI) for anyone to be interested in addressing data interoperability. The RoI can come in the form of time, money or other benefits (such as reputation).

Dr Ferreyra also pointed out that a key problem is the lack of data definitions and no common control vocabulary. This means that even if a company had access to data, if they don't know what the data entails then they can't make any transformations over it to put it in a common format with other data.

This work fits in with AgGateway which is a global, non-profit organisation of over 230 agriculture businesses with the mission of developing resources and relationships that drive digital connectivity in global agriculture and related industries. The key output of this group is the development of data standards and guidelines to enable companies to rapidly access information.

One workstream that has come from AgGateway is the Agricultural Data Application Programming Toolkit (ADAPT). ADAPT is an open source project that will enable the community to build plug-ins for different software and hardware applications with the intent of converting data from one format to another.

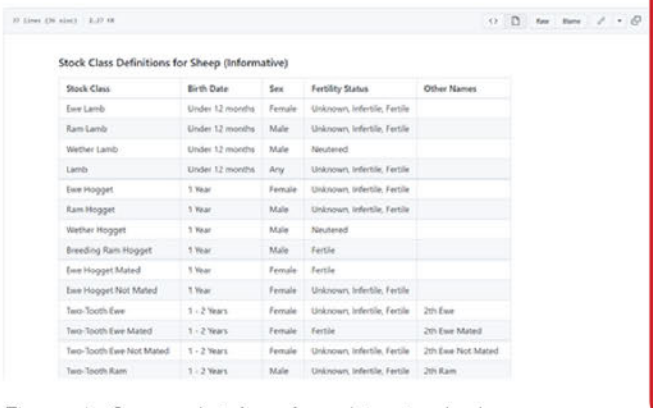
With all of Dr Ferreyra's work, he highlighted the biggest challenge as encouraging everyone to be around the same table. Relationship management is critically important in data interoperability, there needs to be a genuine want to work together. #Letsdothistogether so that trust can be built.

A history of New Zealand's data interoperability codes and systems

From 2014, New Zealand developed a Farm Data Code of Practice and Farm Data Standards along with a way to link these through DataLinker.

The NZ Farm Data Code of Practice is a framework that outlines data rights and expectations that provide farmers with the confidence that their data is managed appropriately and is kept secure. The code helps by explicitly stating to farmers and other users how data is processed, shared, secured and stored. It also helps to provide an understanding to the users of who has rights to the data held. The code of practice was published in 2016 and was developed by seven industry organisations. There is limited uptake of the code and as at January 2023 there were only five accredited organisations of the almost 200 organisations that use farm data in New Zealand.

The Farm Data Standards are a set of commonly agreed data vocabularies to ensure the same definition is applied across the same data points. The information used in the Farm Data Standards is for the design of new software or databases so the data can be used across different applications. This means farmers spend less time on data entry and focus on the insights to make better farm decisions instead. The terms used are commonly used terms on farm. For example sheep definitions are described as:



Stock Class Definitions for Sheep (Informative)

Stock Class	Birth Date	Sex	Fertility Status	Other Names
Ewe Lamb	Under 12 months	Female	Unknown, Infertile, Fertile	
Ram Lamb	Under 12 months	Male	Unknown, Infertile, Fertile	
Wether Lamb	Under 12 months	Male	Neutered	
Lamb	Under 12 months	Any	Unknown, Infertile, Fertile	
Ewe Hogget	1 Year	Female	Unknown, Infertile, Fertile	
Ram Hogget	1 Year	Male	Unknown, Infertile, Fertile	
Wether Hogget	1 Year	Male	Neutered	
Breeding Ram Hogget	1 Year	Male	Fertile	
Ewe Hogget Mated	1 Year	Female	Fertile	
Ewe Hogget Not Mated	1 Year	Female	Unknown, Infertile, Fertile	
Two-Tooth Ewe	1 - 2 Years	Female	Unknown, Infertile, Fertile	2th Ewe
Two-Tooth Ewe Mated	1 - 2 Years	Female	Fertile	2th Ewe Mated
Two-Tooth Ewe Not Mated	1 - 2 Years	Female	Unknown, Infertile, Fertile	2th Ewe Not Mated
Two-Tooth Ram	1 - 2 Years	Male	Unknown, Infertile, Fertile	2th Ram

Figure six, Screen shot from farm data standards, https://github.com/Datalinker-Org/Farm-Data-Standards/blob/master/README.md.

Finally, DataLinker provides a way for organisations and solution developers to share data more effectively by providing guidance and a platform for data solutions to work from. It allows organisations to share the terms and conditions for access to their APIs.

One system that was created out of a need to address data interoperability is Agrigate, which was developed through a partnership with Fonterra Farm Source and LIC in 2017. The reason for Agrigate is to harness the power of farm data by connecting and sharing data between people and systems. It is a permissions based application to help with auditability and traceability of data systems. Agrigate works at the corporate level to develop APIs that can plug into partner systems. The role of Agrigate is relationship based to work with as many of the corporates as possible to access and create external data sharing APIs.

Blair Smith, CEO of Agrigate, made it clear that an API is not always required. An API is expensive and time consuming to create. It depends on what the data is being used for, as to whether an API is the right approach. New Zealand tends to have internal APIs in companies that can share data between a phone app and desktop system so the same data is in both places. However, these are not ideal for external sharing platforms when trying to combine multiple data systems because there could be timeouts of queries given the large numbers of data points that are needing to be pulled.

Technical piece

The benefits and drawbacks of using APIs to connect systems

API access and control is defined by the company and access can easily be taken away

API access is given by the company that holds the data. Perriam et al. (2019) has highlighted that with the growth and popularity in API usage, large companies are starting to restrict access to their systems. Particularly for researchers. Perriam et al. (2019) has explained that API access has become increasingly difficult to obtain due to restrictions and regulations by corporations. These companies are instead favouring access where the API is paid for, this is for marketers and advertisers.

This is a problem because it means there is a trade-off of building tools that rely heavily on API access, which takes time and coding hours to create. What will the driver be to create these tools if access can just be taken away, or price increases to maintain access start to take place? One option to mitigate this is to use contracts, however that adds a significant amount of time to gain access to the API in the first place. Contractual methods could be worth it in the long-run, but the trade-off is time and speed of API development.

Given the amount of time it takes to develop APIs there are a number of open-source tools to assist with this and enable the development community to learn from each other. One of these is the OpenAPI Initiative that is a consortium of members that work together to standardise how APIs are described because they recognise the significant value in this. It comes back to the value and emphasis that needs to be put on the relationship and building trust with other parties.

APIs can cause security breaches

In 2019 it was estimated that 83% of all web-traffic was API related. In 2022 APIs were also considered to be among the most frequent attack vectors and many of the major data breaches that occurred had involved APIs as part of the attack (Hawes and Bell, 2019). APIs need to be well looked after and kept secure.

API benefits far outweigh the challenges

Even though there are challenges associated to the development, maintenance and access of APIs the benefits far outweigh these challenges. Listed below are just some of the benefits of APIs (Medlicott, 2022):

1. APIs are continually getting better and developers can get ahead of the detail.
2. Once an API has been created for access to an external (or internal) data system, when upgrades happen most of the base of the API can remain the same, saving time and complexity.
3. Load times for data are much lighter and less prone to human error, as most are automatic.
4. Good API design can lead to greater alignment to the company.
5. APIs enable efficient data distribution.

Section two summary

In summary there are a number of challenges and potential solutions to address data interoperability. For a way forward on data interoperability there are three essential elements required:

1. Strong interpersonal relationships between users and companies that are based on mutual understanding and trust.

2. Clear data definitions of what data is being collected.

3. Development of external sharing APIs to connect various systems and provide doors to data.

Figure seven, Image from milking robot computer in Indiana, author's photo.

Section three

On-farm data maturity

Practical examples of using APIs

Where data interoperability works is with smaller companies that work directly with their stakeholders. They are able to offer a customised solution for their clients. They are also more accessible when things go wrong or there is a breakdown of a system.

During interviews undertaken it was suggested that once a company reaches a certain size they lose the direct relationship with customers and serviceability drops. There is a sweet spot for the size of the companies that work with their stakeholders and offer the best solution. When it comes to data, relationships are key.

Access to APIs is based on relationships because a company has to grant access to other companies to use the data held. For public information, such as weather, this is granted automatically. As data becomes more sensitive and private this leads to more stringency on API access and it this is where relationships become increasingly important.

Supply chains using APIs to collate information

The supply chain sector is a big user of APIs to collate information. An example of this working well is when businesses need to book air freight space. Webcargo.co pulls the information from each airlines' website to show it in one interface so it is easier for customers to see routes, times, and prices and book from there (see figure seven). The different websites talk to each other to pull and push data.

The payment process then goes back through individual airline websites and is booked directly through them. This saves time, costs, and means customers are able to book the best solution for them depending on the parameters they require for the product to get to its destination.

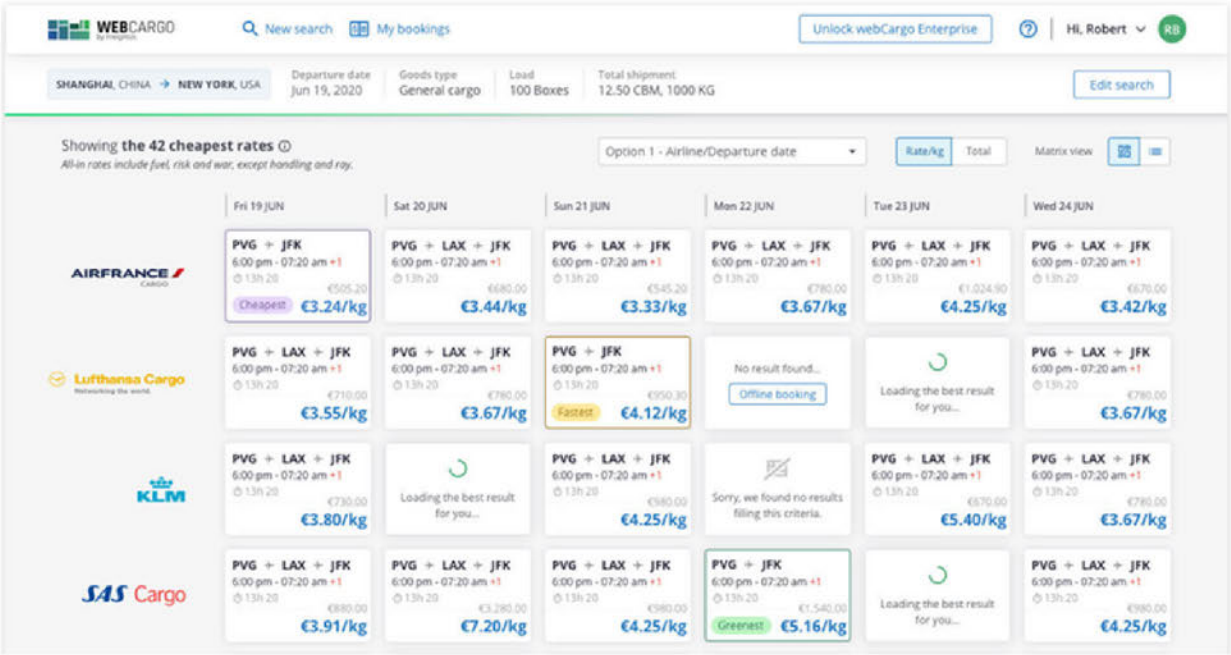


Figure eight, Example of APIs in use (https://www.webcargo.co/live-ebooking-status/)

farms are not standalone - the era of consumer connections

Farm systems are complex, there are a significant number of inputs, processes and actions that take place to get an output.

Figure eight is an example of some of the processes within a farming operation

Farming systems:

A farm is a system, with inputs, processes, and outputs

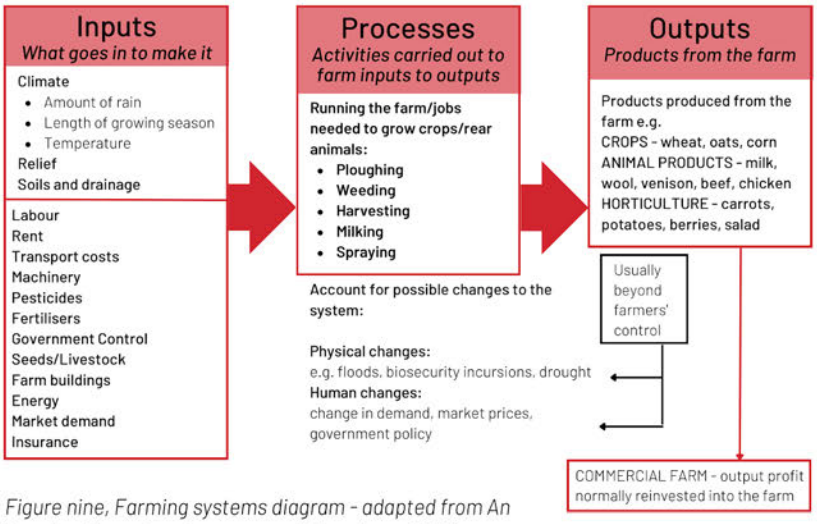


Figure nine, Farming systems diagram - adapted from An introduction to farming systems (Chambers, 2008)

Figure eight shows the processes, inputs, and outputs that occur within the farmgate. As described earlier, there is a much wider ecosystem in place. A farm fits into the wider ecosystem through to the consumer.

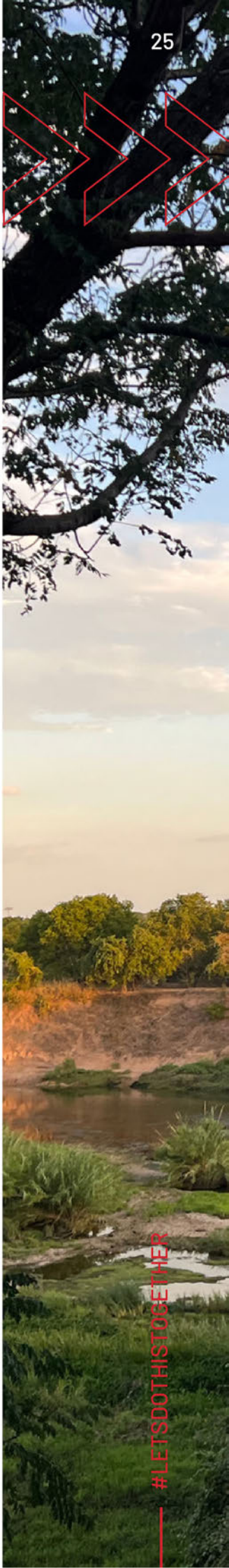
Right through the supply chain entities are requiring data and proof of the claims being made on farm. Traditionally farms have been conservative with data sharing as they do not know the purpose it is being used for or by whom (more on page 28). We no longer have the luxury of doing that. Without being transparent on what is happening on farm and the operations taking place, consumers have less of an understanding of how farms work and where food comes from. This has created a distorted view of farming and there is a significant amount of negative media on farming operations with misconceptions associated to it.

Farmers need to have a voice and show what is happening on farm – this is why programmes such as ZQRX (page 11) are so important to building back an understanding at the consumer level of what farming is.

Data interoperability helps farmers to tell their story, where the farm came from, and where it is going. Farmers sit in a wider ecosystem, they are not islands.

By addressing data interoperability on farm, the information can be used to build connections with each other that go much further than the farmgate. With the current focus on the big challenges of climate change, biodiversity loss and food security, data sharing will soon become mandatory to continue to operate (for some consumers it already is).

Transparency has never been more important that now, in a post Covid-19 world where we need to build back consumer trust in farming and food production. There are multiple feedback loops as shown in the *Wider farm ecosystem* on the following page.



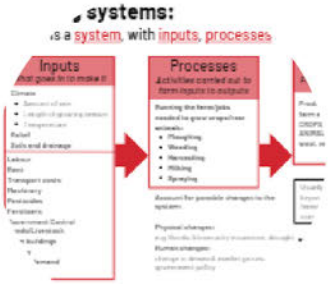
Wider farm ecosystem

Consumers

Retailers

Manufacturers and processors

Farmers



Suppliers

#LETSDOTHISTOGETHER

New Zealand's data interoperability space

Traditionally New Zealand had quite a reserved data sharing culture within agriculture. Five to ten years ago, data held in agricultural companies was considered a competitive advantage, that attitude has changed and there is a genuine desire to work together. New Zealand's agricultural leaders understand the drivers and needs for data interoperability and there is a genuine desire to address the challenge.

However, it is not a straight forward path. Agricultural companies have a number of competing drivers for limited IT resources. There are constant improvements and upgrades required to their internal and customer facing technology systems putting pressure on limited resources. This means that data interoperability is not the key focus for many companies nor is the development of external data sharing APIs – it is not because they do not want to do it, it is that there are no resources left to get it done.

What this has created is an ecosystem with a number of bespoke data capture and collation solutions. Some systems will interact with others, however there is no single system in New Zealand that is able to connect all data. Callaghan Innovation has developed the Agritech Knowledge Hub that was launched in December 2022. This provides a snapshot of just how many different bespoke solutions there are for our farmers and growers, and more are being added every day.

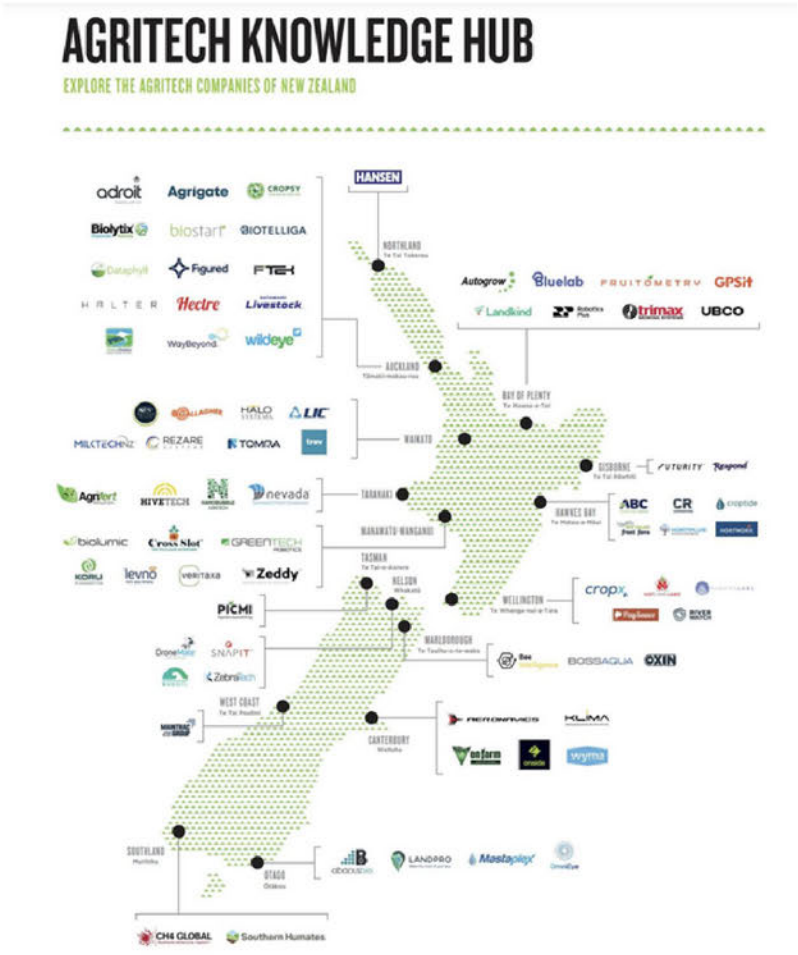


Figure ten, Agritech knowledge hub – Callaghan Innovation - https://agritech-labs.co.nz/knowledge-hub/

New Zealand is an innovative country and if we come together we can work through the technology challenges by leveraging our relationships with each other.

Relationships are key to address data interoperability and with our agricultural leaders prepared to work together, we are already a step ahead of other countries.

New Zealand is well placed to address this – we are made up of predominantly co-operatives who look after the best interests of farmers, and we are a nimble and agile society, if anyone can find a way forward it is us. #Letsdothistogether.

Farmers want to share data and get the best value from it

In 2022 Agritech New Zealand commissioned a study (the Report) that surveyed over 1000 farmers and growers in New Zealand and looked into their attitudes towards digital adoption. It also covered a significant piece on attitudes to data sharing.

A key finding from the report was that 41% of surveyed farmers could not see much value in using digital technology in their business. This was not unexpected because in New Zealand knowledge levels of data sharing are low and the value of data sharing has not been unlocked. The report also tested the attitudes towards data sharing and found that 77% of farmers and growers will share data if it benefits them directly. This is a very high figure and shows the potential of unlocking and creating benefits for farmers and growers around data sharing.

The Report found the biggest barrier to data sharing being the lack of understanding of how the data could be valuable to others. Confusion, mistrust, and fear around data sharing is created because farmers and growers are unsure of who is accessing the information and why. This is critical to understanding the perceptions, where confidence in sharing data is found by clarifying who is using the data and for what purpose.

An emerging company on the market that understands these challenges is PureFarming. PureFarming uses APIs to enable data sharing between different agricultural companies. As discussed earlier, APIs enable on-demand transfer of data between agricultural databases and technologies. PureFarming is connecting data from farms within the agri-food supply chain, this is becoming increasingly important with the pressure on consumer facing organisations to understand their scope three emissions. PureFarming uses APIs to enable these connections, the platform is free for farmers and growers to use, and it costs money for industry who 'buy' the data from the farmer/grower. Many companies want to access the same data from farmers so using the PureFarming platform means:

- less duplication of data entry,
- ability to provide production transparency,
- provide farmer insights,
- measure scope three emissions,
- enable farm assurance, and
- an ability to authenticate users.

Farmers and growers have complete control over their data and they provide permissions to determine *"what data is connected, who can use it, and under what terms."* It is a single point for industry to be able to request and access farmer and grower data.

Another critical challenge the Report highlighted is that 55% of surveyed farmers and growers found it difficult to pick which technology system and solution would actually be beneficial for their business. There is no independent verifications or reviews of the various technology systems and there are multiple solutions to the same problem, so how does a farmer or grower know which one is best for them? They will have to do the research themselves and if their current system works, then there is not the time or drive to investigate multiple new systems.

The top three barriers to technology uptake were identified as:

1. Cost
2. Reluctance to move from manual systems that work
3. Return on Investment (including time and labour savings)

A really interesting fact from the Report was that proud traditional farmers and growers disliked change because what they have always done on the land works. There is an acceptance that offices use technology for various applications, such as booking contractors and fertiliser with the **key being that someone else is doing it.**

Section four

Case studies

Data interoperability examples from around the world

I travelled overseas to understand what other countries and agricultural companies were doing in the data space. I spent roughly four months overseas during 2022 spending time in the United Kingdom, Norway, the Netherlands, The United States of America, Canada, Australia, and New Zealand.

Bigger is not always better

Before I left New Zealand I had an assumption that bigger companies would be better placed to have addressed some of the data interoperability challenges. I had this theory as big companies have the resources and size to influence change. For this reason I visited a large salmon farm in Norway. Norway's salmon industry is made up of few, large players because there is a high barrier to entry as significant capital is required to set-up a fish farm. Fish farming is also an emerging industry so they have the benefit that they are able to innovate and not be held to account on established methods of operation.

When I spoke to the Norwegian salmon farmers it became clear very quickly that they have as many data interoperability challenges as other industries. Yes, they are big. However, this also means that internally different departments use different systems for their area of expertise. What this creates is that the fish health system does not link to the production or sales system – health statistics cannot be traced back to what the production and sales volumes were. To view the overall operation, these systems needed to be manually matched using spreadsheets and other analytical tools. The systems they were using were highly capable in their own right, however they lacked the ability to share data between the systems within the same organisation.

During the course of my travels I visited a number of agricultural companies, farms and support organisations across various sectors and of varying sizes. These visits enabled me to take a deep dive into the challenges of data systems and how some companies are addressing the complexities within data ecosystems. The next section of this report will outline ten case studies of companies and systems I came across and what they are doing in data management and interoperability.

Norwegian salmon farm, author's photo

Case study: Penley

Collecting data on a vineyard, South Australia

Penley is a digitally advanced vineyard in South Australia. It is actively deploying and testing agritech that addresses specific challenges they face to achieving quality and yield outcomes required for the business' strategic direction. While not the intent, Penley has found itself at the bleeding edge of innovation and viticultural data management.

Penley.

Through a data audit and understanding of which indices, correlations, and calculations provided outputs of greatest value to Penley, the viticulturist quickly identified the need for a database to store these key data sets. For optimum efficiency, data should be collected directly in a digital format for ease of transfer and upload; in practice this is not necessarily the case. Even a digitally literate business such as Penley continues to collect the odd pieces of data in hard copy format and has also encountered the issue of non – data friendly export formats such as pdf.

Penley works closely with EarthSQL which manages the data lake and is able to visualise the key information back to Penley. The challenge Penley has is that the data needs to go to EarthSQL in a digital format for it to sit in the data lake. With the various technology systems and vineyard management systems used on the vineyard some of them are not digital. As an example, Penley was working with a very large, multi-industry company to map vineyard activities (such as spraying) and when they asked for the data back it could only be exported as a pdf document. This is not a shareable form and requires the data to be translated into a digital form to be compatible with the data lake.

When Penley searched for another vineyard mapping tool, it found one that is more specialised and works predominantly with vineyards so is customised and customer focused. This solution was great for Penley as it was able to work with the company on what it needed from the system. It also exported the files in a shareable format using csv. However, working with the smaller companies means they are also more glitchy, one challenge from this business was that their spray diary platform was not as mature as expected and turned out to be quite glitchy. This has resulted in a loss off efficiency in the first year of adoption, with spray records needing to be recorded manually by the vineyard manager, as opposed to an app-based system with details filled in by operators at the time of application.

Spraying is one of the most important roles in vineyard management and needs to be monitored very carefully for different types of wine certifications and government regulations. Having the system down for a significant length of time with no back up can be detrimental to a vineyard running a small team and requiring optimum efficiency in achieving legislated reporting requirements within time bounds. Trust is also lost in partners who cannot deliver the service that was promised.

Being a first mover is not easy and means constantly dealing with glitches, however we cannot afford to stay still, the industry needs heroes like Penley.

#LETSDOTHISTOGETHER

Case study: EarthSQL

How EarthSQL works directly with customers on data management, Melbourne, Australia

EarthSQL began in the mining sector in Australia where the value and insights gained from strong data management and visualisation to connect different systems are well understood. Mining companies are able to manage their data with the help of EarthSQL at a level that is appropriate for them and their size. They all receive a customised solution.

"EarthSQL specialises in efficient, affordable systems for solving complex data problems, including customised interfaces for enhanced data visualisation."

EarthSQL holds company data in a cloud based SQL database. The data is digital and maintained by EarthSQL, customers do not need to deal with obscure raw data formats and API feeds. EarthSQL uses Microsoft stack, including systems such as PowerBI, to create ready to use exports and to visualise the data so that customers have the insights they require for their business. By having digital data it enables external data sharing with the permission of the customer, this can be to service down-stream customer requirements or regulatory functions.

EarthSQL has recently branched into the agriculture space in Australia, particularly viticulture, where it is working with a vineyard, Penley, in South Australia to digitally store and manage its data. EarthSQL has created a viticulture data system that enables new insights to be gained. This is through a Collabriculture logic data model, input field observations, sensor data, third party data, output season reports, crop estimates, comparisons, trends, spatial visuals using PowerBI and GIS. Being able to capture, hold and visualise this data provides significant value to Penley as seen in the first case study.

The role of Collabriculture

Collabriculture is an Australian platform for open collaboration. Their first project is the Open Vineyard Data Model. This project brings together stakeholders and GIS experts to describe vineyard attributes such as posts, trellis wires, vines, rows, and blocks to enable digital vineyard maps to be created, stored, and shared. The objective of the platform is to make vineyard mapping commonplace, standardised, and FAIR: Findable, Accessible, Interoperable, and Reusable.

As an industry, mining and exploration regard data management and data warehousing as a standalone discipline that is resourced by employing dedicated staff into these roles.

This allows other professionals to understand the data and insights they receive and turn this into knowledge. This same concept can be applied to agriculture.

Figure eleven, Mining image courtesy of Tom Fisk

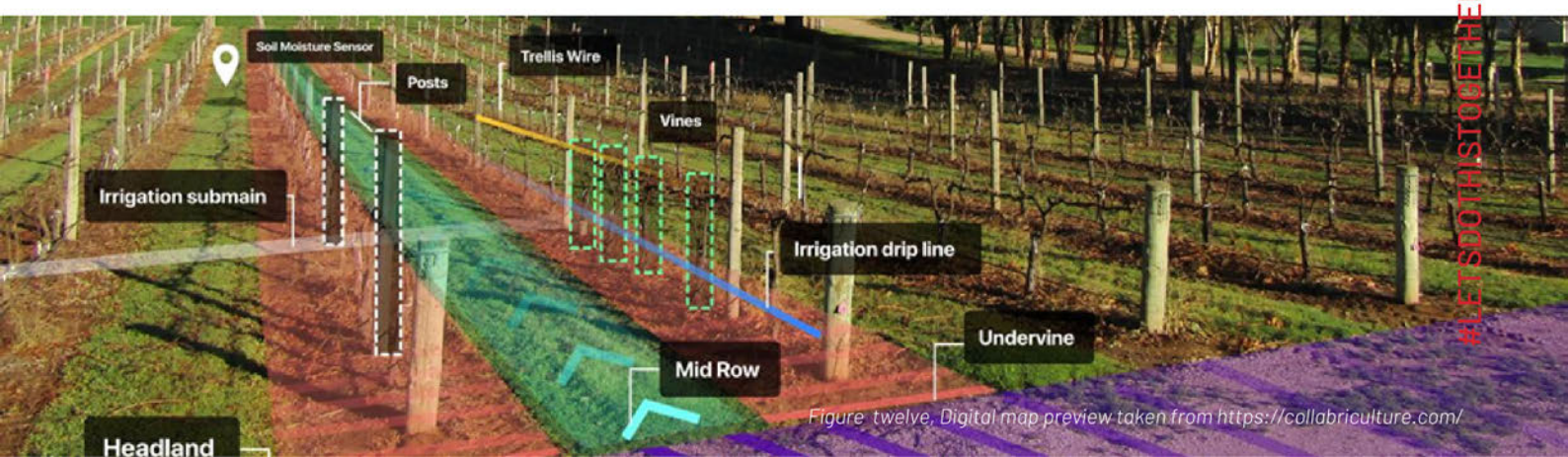


Figure twelve, Digital map preview taken from https://collabriculture.com/

Case study: Smithfield Cattle Company

Employing a Business Intelligence Manager, Queensland, Australia

Smithfield Cattle Company (Smithfield) is a family-owned business that runs two 20,000 head cattle feedlots in Queensland. Smithfield has a strong reputation for quality and animal welfare on its lots. Using state of the art tools and innovation it is an industry leader.

Smithfield wanted to better understand its feedlots and to work with data to optimise its operations. In conjunction with Meat and Livestock Australia they embarked on a journey to employ their first Business Intelligence Manager (BI Manager).

Meat and Livestock Australia was interested in what could be achieved on a feedlot by a BI Manager, so they could share best practice data management and reporting on systems across the farmer network.

The BI Manager's role is to make data accessible to the feedlot managers and staff so they have access to information at their fingertips and can make timely decisions to optimise operations. The key is to digitalise the data.

The BI Manager works closely with the feedlot managers to understand exactly what they are collecting, why they are collecting it, and what they need it for. The BI Manager is a problem solver and is there to simplify the role of data on a feedlot. The following are the core drivers of the BI Manager:

- Single data entry on the feedlots.
- Extract data from source systems by means of automatic update or through APIs with the goal of having all the data in a data lake in the cloud.
- Automate reporting cadence to reduce manual collation of old excel/powerpoint reporting.
- Use PowerBI visualisation software to visualise the data back to the feedlot managers and teams.

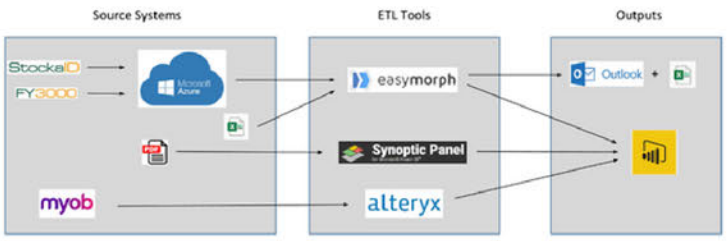


Figure thirteen, Process Smithfield's uses to digitise the data

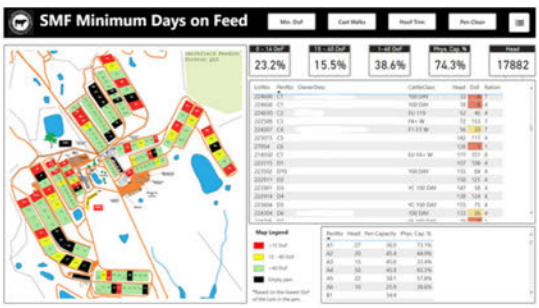


Figure fourteen, Digital map of Smithfield feedlot in Proston, image provided by Smithfield

What Smithfield has achieved through its BI Manager is incredibly powerful. Speaking to the feedlot managers they get a great deal of value and business improvement ideas from the information that is shared back to them in a timely manner.

#LETSDOTHISTOGETHER

Case study: Angus Soft Fruits

Data management for Angus Soft Fruits, Arborath, Scotland

Angus Soft Fruits is a berry specialist that breeds, grows and packs berries for the UK and European markets. It is able to guarantee year-round supply using its global partner base. It grows soft fruits including blueberries, raspberries, strawberries, and blackberries. It supplies predominantly United Kingdom (UK) supermarkets including Sainsburys, Aldi, Marks and Spencer, Morrisons, and Asda. These account for approximately 15% of the UK market.

The size and scale of Angus Soft Fruits (Angus) enables it to employ its own data manager. The data manager at Angus is the first IT person they have employed. They are responsible for collating various data points for the business and producing holistic dashboards for the leadership team. A significant part of the role is data science and understanding the various data sets and how best to put these together. Prior to the data manager the various departments within Angus were operating in silos and the leadership team was receiving reports from each department individually, such as people data, production, and spray calendars, now this can be received in one dashboard to view Angus holistically.

For the data manager to achieve this a key element is having digital data sets hosted and stored on cloud services to analyse the data.

Hosted Services	Cloud Services
Amazon Web Services	Software as a Service
Microsoft	PowerBI
Google	Tableau

The **hosted service** is the hardware and servers that are used to store the data. While the **cloud services** do the analysing of datasets that are held in the hosted services. To achieve this the digital data uses common data standards so it is consistent and clean data.

The data manager aims to develop a standard set of dashboards that show what each stakeholder is interested in:

- Farmer/grower – The information and data they need to optimise their growing of berries.
- Management teams – Information on their departments and how that contributes to the wider goals of the business.
- Leadership team – Holistic view of the business from farm production through to sales and forecasting of the business.

The biggest challenge Angus has is that the partner growers it works with are worldwide and they do not just grow berries. These growers have multiple partners with the other fruit and vegetables they sell, this means almost every grower has a different system and method of managing their farm and calculating growing variables and results. It is difficult for Angus to enforce certain systems for them to use which means they have a challenging time pulling the data together. For 2023, one of its top priorities is around data management and understanding what its growing partners are doing with the berries. A wider supply chain understanding is becoming increasingly important for customers so they can prove to consumers that they are operating by the values they have stated.

Figure fifteen, Background image of Scotland orchards, courtesy of Angus Soft Fruits

Case study: EasyMorph

EasyMorph data transformation, Toronto, Canada

EasyMorph was founded by Dmitry Gudkov in 2014, it is an advanced tool that enables data manipulation by non-technical people who can transform data without needing to code. It is an interface between pulling the data from a system using an API (or other connectors like uploading an excel file) and then transforming it into the format that will be used to consolidate data. It is a user-friendly data transformation tool that is used by over 500 organisations over five continents. There are over 150 built-in actions users can apply for fast and visual data transformation without needing to code.

EasyMorph Server is a data transformation, API integration, and business automation server designed for self-service, privacy, and simple administration. The Server runs visual workflows designed in EasyMorph Desktop. Its typical use cases are:

- Scheduled data preparation and heavy ETL (Extract, Transform, and Load) tasks.
- Real-time and scheduled integration between enterprise and cloud applications (e.g. via APIs).
- Multi-format data collection and consolidation.
- Governed delivery of business data to employees and external parties.
- Offloading of resource-intense EasyMorph workflows from Desktops.

EasyMorph has just released a new tool that enables the platform to custom build APIs. This is incredibly advanced and removes the long lead times for API development.

Case study: Nijkamp

Family poultry and dairy farm using data, Raalte, the Netherlands

I met with the Nijkamp family in the Netherlands. Robert Nijkamp is Nuffield Alumni and in 2018 he undertook a topic looking into on-farm data for his chickens. His aim was to retrieve data from each poultry shed and match this with slaughter data so he could get greater transparency on his operating system to enable optimisation of growth rates.

Robert Nijkamp has built an impressive state of the art chick rearing barn. When the chicks arrive they are kept for eight weeks. They are slow growing grade one chicks with higher animal welfare than the average Netherlands farmer. When in the barn they get a lot of natural sunlight and natural air flowing through the space. Robert has an advanced system that has the capability to monitor CO2 and ammonia output. He uses an API to integrate the data from the poultry house feed and water intake, ammonia, and CO2 levels into a dashboard. He also uses blockchain to enable traceability of his systems.

What Robert would like to achieve is have all the data management and tools connected so he can make stronger decisions from them and be able to forecast and detect diseases much quicker.

The farmer and data foundation, set up in 2020, came from Robert's Nuffield project. The farmer and data foundation is a group of farmers that have banded together from various livestock farms. The foundation works closely with farmhack.nl (2019) with the aim of seamless data flow. The intent of the foundation is to take back control of data by working on data projects that exchange data with various systems to achieve interoperability. The aim is for each farmer to determine whom that data will be shared with and for what purpose. The ultimate goal is to obtain a financial return for sharing the data with outside organisations.

The significant challenge Robert is facing is getting data back from the slaughter companies. This is notoriously difficult and the slaughter companies are large and powerful organisations that do not take kindly to farmer demands. What this has resulted in is Robert working with an IT consultant who can data scrape [2] the websites where the slaughter data is held so that Robert can pull it out and conduct his own analysis on it.

Robert was using data scrappers to retrieve the data on his own terms. He acknowledged that there is a lack of movement in achieving farm level data interoperability because some farmers cannot see the value of data and the unions do not help with it as it is not a priority for them.

What is FarmHack.nl?

FarmHack.nl is comparable to the Agtech hackathon competition that is run annually in New Zealand. The driver behind FarmHack.nl is that digitalisation in agriculture to date has focused on increasing efficiency and productivity for farmers. They are trying to flip this to focus on developing sustainable food production systems with farmers by using the full potential of data and technology.

FarmHack.nl considers themselves as the catalyst for solutions and innovations in the agricultural and farming sector. They mobilise coders, developers, creatives, and domain experts to tackle IT challenges that farmers are facing. They create new value propositions by building data driven partnerships to address challenges in an open and transparent manner.

[2] Data scraping, also known as web scraping, is the process of importing information from a website into a spreadsheet or local file saved on your computer.

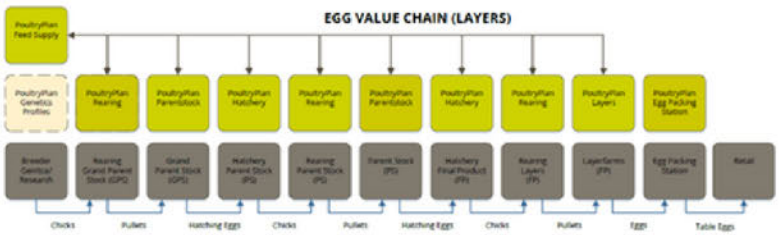
Case study: PoultryPlan

PoultryPlan
TURNS YOUR DATA INTO GROWTH

Digitising poultry data, Duiven, the Netherlands

In the Netherlands, Chiel ter Heerdt was the managing director of the Ter Heerdt company, which is a poultry business that experienced a significant amount of growth. Chiel was frustrated there was no software solution on the market to help provide a better overview and planning capabilities in his business. Chiel then created his own software and thus PoultryPlan was born.

PoultryPlan can service both layers and broilers, the leadership team of PoultryPlan is from a poultry background. The team has practical experience and a working knowledge of how the farms operate. It has created strong relationships with the farms and organisations it works with to provide a holistic overview of the operation, throughout all aspects of the value chain:



PoultryPlan uses an Enterprise Resource Planning (ERP) system in the Cloud that ensures a better overview of the value chain to enable preventative control, leading to more profitable poultry farms. ERP is a type of software system that helps organisations automate and manage core business processes for optimal performance.

PoultryPlan puts a lot of emphasis and value on having the knowledge and expertise in the poultry industry coupled with software development to tailor solutions to individual customer requirements. Customers can easily see these on either a dashboard or phone app:

Chiel described the biggest challenge as working with smaller farmers and getting them to recognise the benefit of using the system. His main client base is currently with slaughter houses and larger operations.

Chiel wants farms to be able to benchmark against themselves and the wider industry so there is an option for farmers to share the data so it can be used for benchmarking. However, farmers can choose not to share their data but then they also do not get to see how they benchmark.

PoultryPlan is a strong example of where software companies can be successful when they can work directly with farmers and can speak the farming language.

Images supplied by PoultryPlan

Case study: Salt and Tonic

Sharing data in tourism, Rotorua, New Zealand

Salt and Tonic is an innovative, New Zealand based company that helps industries address traditional problems with data mapping and visualisation. It has worked extensively with the tourism sector, particularly experience tourism in Rotorua, to understand when their peak bookings are, peak times, and to forecast future bookings. Customers are able to benchmark themselves across the rest of the industry in Rotorua and this can be segmented by demographics and regions. This provides powerful insights into the tourism industry to help with planning and optimisation of businesses.

SALT + TONIC

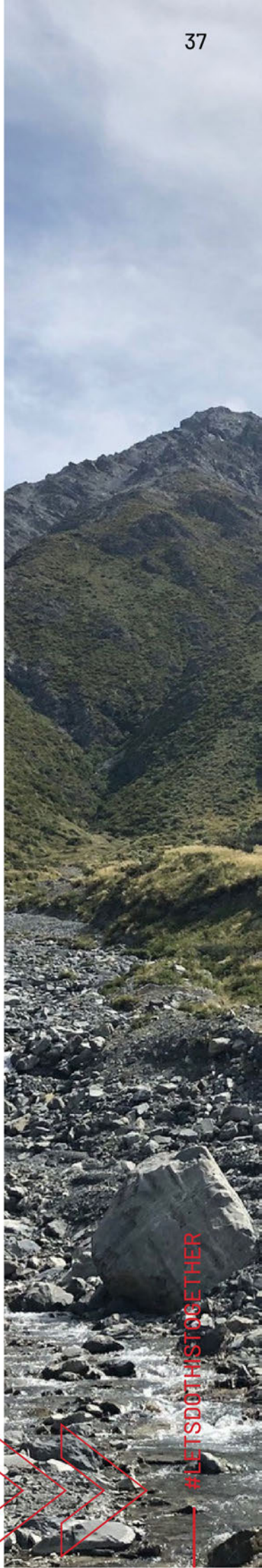
Salt and Tonic has recently branched out to the agriculture sector where it has worked with an agriculture company in Taranaki to build a platform so it can understand its data. APIs pull the data enabling the customer to see its operations but also benchmark with the agriculture sector it sits in.

An avocado business has reached out to the company recently to create greater connection across its data. The value of its service is being recognised across different sectors and customers.

The key to Salt and Tonic's success is the use of APIs. APIs allow pulling of multiple systems into one visualisation or dashboard, depending on what the customer wants to see. The data dashboards it creates allow the customer greater perception and control about what is happening with up to date information, and grouped to allow better insights from the data that already exists. It is not creating new data.

APIs are the gateway to different data systems, however New Zealand is still in the early stages of recognising the value of APIs. In the USA, a start-up has to have a strong API to survive, if they don't - they fail. There is a much greater data sharing culture in the USA than in New Zealand. To get access to APIs, permission must be granted from the original database. An example of how this can be challenging is where Salt and Tonic had created a support ticket with a company to access its API and it took nine months for the other company to respond to it.

Relationships are incredibly important when it comes to APIs and a willingness to open and share data. If done right this can be a very strong reciprocal relationship – but the value needs to be understood.



Case study: ClimateFieldview

Bayer Crop Science providing one solution, USA (headquartered Germany)

Monsanto, which was acquired by Bayer in 2016, bought Climate Corp for nearly $US1 billion in 2013. The Climate Corp was founded in 2009 by former software and data specialists from high-tech companies, including Google. In the beginning, the company mainly focused on weather data. Now it goes much further than that into the revamped Climate FieldView system which is a very powerful system.

Climate FieldView collects, stores, and analyses field data in real time. It is an all-in-one management tool for arable farmers.

The tool is well used by farmers across North America and enables comprehensive capture of data from planting maps, spray maps throughout the season, and yield maps at harvest. To see this in real-time a device known as 'FieldView Drive' is an in-cab hardware device that captures machine and field data without manual entry, this connects with the Climate FieldView platform.

As at January 2023, Climate FieldView had 28 partners that connect into the platform. This includes machinery manufactures John Deere and Claas. The platform now monitors 72 million hectares (almost three times New Zealand's land area) across 20 countries. It is sitting on a treasure trove of data that Bayer has access to, this begins to raise ethical questions (Carbonell, 2016).

The challenge for Bayer is how to maintain independence, as it sells the seed, it sells the pesticides to protect and grow that seed, and now it sells the software tool to best manage that seed through to harvest. When speaking to Bayer Crop Science in North America, it is continually improving the tool for the benefit of growers. Arable farmers who use the tool value using it and being able to see the productivity level of every section of the field. It provides visual views of the field that the grower can immediately register what is taking place on that field.

It is a very good system and works for growers, if they have all the supporting software and use the right brands of machinery. Growers need to remain aware that Bayer Crop Science and the other 'big tech' companies now have the capability to collect vast amounts of data with the aim of getting direct access to their customers' fields and this feeds into the selling of their products (GRAIN, 2021).

Case study: DJustConnect

Data exchange platform, Belgium

DJustConnect was launched in 2020 and is an independent data exchange platform from Belgium. The platform is based on the same premise as PureFarming on page 28.

DJustConnect uses APIs to exchange and transfer data between the data provider (farmer or grower) and the data consumer which could be government, suppliers, buyers, producer organisations, or corporations. The farmer has complete control on who has access at any time and can revoke access as well. A big driver to set up this data sharing platform was to develop innovation in agriculture for Belgium and across Europe, so a technology developer can gain access to farmers' data to prototype and test if the technology works. This significantly speeds up innovation in big data management on farm and technology development.

This is now being connected across the European Union where:

"ILVO (Flanders research institute for agriculture, fisheries and food) is also leading one of these case studies, by collaborating with the Flemish data sharing platform DJustConnect with the French data sharing platform AgDataHub. The aim is to be able to exchange data between the platforms in order to provide an example of how this could be done at the European level. In this way, we are working toward a federally-structured European data space." (Chatzikostas, 2022)

The platform is part of the Data4Food2030 programme being undertaken by Wageningen University in the Netherlands. This programme started in 2022 and runs through to 2026 with the intention to develop a pathway towards a fair, inclusive, and innovative data economy for sustainable food systems. This aligns to the UNs intentions around data to meet the SDGs.

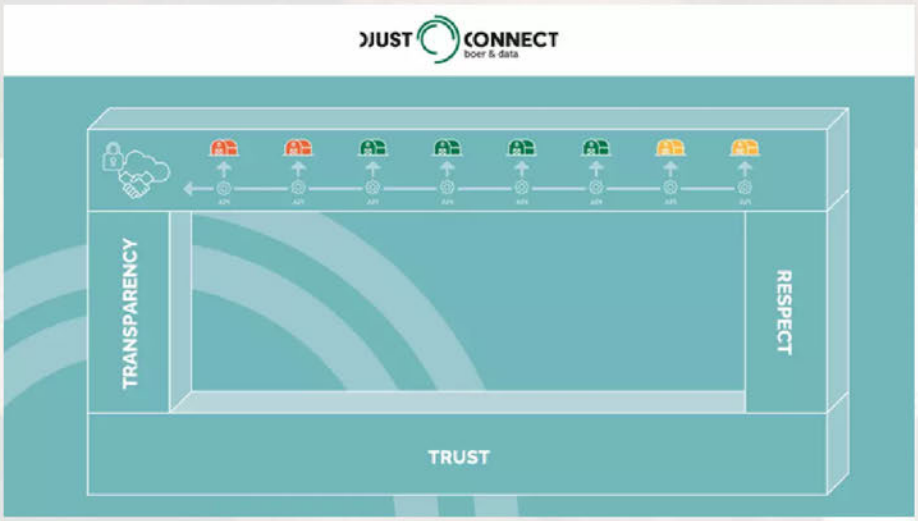


Figure sixteen, Process diagram of how the platform works taken from https://www.djustconnect.be/en/who-are-we

#LETSDOTHISTOGETHER

Section five

An alternative way forward

Power back to the farmers and growers

Data management is no longer optional for farmers because they are being asked to provide data to a growing number of different stakeholders, from local government through to processors. When it comes to finance and accounting we are not asking the farmers to be experts, instead this is outsourced to an expert and all business owners receive a bespoke solution from the accountant. So why are we asking farmers to be data experts?

Farmers know what they want from their farm and every farmer has different drivers. Some farmers are passionate about herd management and animal welfare, other farmers could have strong financial drivers, then there are farmers where soil quality and growth rates may be their key driver. All farmers are different so we cannot treat them all the same. A bespoke solution and personal treatment is required, the accountant model could be applied to data management.

Lake District, United Kingdom, author's photo

Create an enabling environment

Role of Government

The New Zealand Government needs to influence industry to prioritise the development of APIs so data can be shared externally, with the right permissions, from agriculture companies.

Agricultural data standards are important but they can be worked around using APIs to pull data and then using ETL (Extract, Cleanse, Transform, and Load) processes to manipulate the data to a standardised format. It is more important that the data has a clear definition associated to it, that clearly states how the data has been collected and what parameters it has. With a clear definition a transformation process can be undertaken to match data sets. Government's role is to create an enabling environment for industry and farmers to be in a position to share data.

The Accountant of data

"A new profession – the Data Manager"

Smithfield Cattle Company (case study page 32) is able to utilise a BI Manager within its business because it has the scale to enable this. There are not many farming and growing companies in New Zealand that have the scale to employ their own BI Manager so a way needs to be developed so this role can be shared across a number of farmers and growers.

Each farmer and grower in New Zealand will have different drivers for matching data and systems. Some will want to access the data and get information on their own operations so they can improve their systems, others will just want it so they can automatically meet regulatory and reporting requirements without having to enter the same data multiple times for different reports and purposes.

Consider that we have a team of data managers based in New Zealand's prime farming locations. Each data manager will have a portfolio of farmer/grower customers to assist with their data needs and advise them on the best way forward for their individual motivators. The data manager will hold and store the data and provide the farmer/grower with the insights, dashboards and/or reports that they require. The data manager is the farmers' key contact and can advise on different solutions and tools to optimise their farming journey. The data manager will stay on top of the latest trends, apps and tools to help farmers and provide a summary of these as appropriate. They are in essence a data manager and adviser. This concept has worked for larger organisations where they have employed a data manager and they work directly with each of the property managers to optimise performance – see case study on Smithfield Cattle Company on page 32.

This pathway forward combines the ideas around a few of the case studies explored in section four of the report. The data manager will work with multiple farming and growing businesses and use cloud based storage solutions (hosted services) and analyse the data using cloud services to provide it back to the farmer/grower in the visualisation that is best for them. These will be bespoke solutions.

Power back to the farmers and growers

Further down the track once all the data is cleansed, and transformed there could be an option for farmers to sell their data externally. They could be capturing an economic value from their data to help pay for the data managers. This was part of the philosophy behind the Nijkamp family poultry farm (see case study on page 35).

Steps a farmer or grower needs to take alongside the data manager

The eight steps to set up a successful relationship between the data manager and farmer or grower are:

1. Farmer/grower has a strategy session with their data manager to understand what they want to achieve from the data.
2. Data manager completes an audit of current data systems.
3. Data manager conducts a gap analysis to determine what pieces of data are missing or inadequate for the farmer/grower to achieve their strategy or vision.
4. Data manager recommends any additional systems, if needed, along with costs and benefits – this is independent advice.
5. With permission from the farmer/grower the data manager works with the system support team to access the API to pull data out of the system. If no API is available then other tools can be utilised such as data mining.
6. Once the data is combined in a data lake on the cloud, the data manager can clean the data.
7. The data lake enables the data manager to undertake analysis and pull reports and dashboards for the farmer/grower so they can visualise and read the results of their farm performance.
8. The data lake also enables the pushing of data back to systems and compulsory reporting requirements to meet regulatory requirements.

Data lake vs. data warehouse

There is a lot of discussion in data management around data lakes and data warehouses. They serve different functions. The difference between them has been well summarised by Talend (2023):

	Data lake	Data warehouse
Data structure	Raw	Processed
Purpose of data	Not yet determined	Currently in use
Users	Data scientists	Business professionals
Accessibility	Highly accessible and quick to update	Complicated and costly to make changes

A data lake offers more flexibility than a data warehouse because it holds all the raw data in an unstructured form. Raw data flows into a data lake, sometimes with a specific future use in mind and sometimes just to have on hand, it has no pre-determined use. However, this means a significant amount of more storage space is required when using a data lake as more data is being stored.

A data warehouse is processed data that has already been appointed for a use. Data warehouses are cheaper to maintain as there is less data stored.

In farmer and grower solutions a data lake will be the key tool employed as it allows greater access to the data and it can be used for multiple purposes further down the track.

Way forward scenarios

Four scenarios to show how this works in practice:

- Bob is a about to retire and farms because he loves the connection to the land

- Mary is young and innovative and wants the best from her farm operation

- Tane is a successful farm manager focused on environmental performance and the farm he manages is on Māori land

- Andrew is a large mid-level farmer and has multiple farming operation interests but each is using different systems and he does not wholly own them

Bob - Semi retired farmer

Bob is a semi-retired sheep and beef farmer. He has worked his farm for the past 40 years and loves being on the land. His farm is under-stocked and his children do not currently have an intention to take over the farm.

Bob has no debt on the farm and he is not aiming to optimise farm performance, he just wants to keep his way of life.

Bob is heading towards retirement and does not want to deal with the bureaucracy that comes with farming he just wants to meet the regulations as required and look after his land and animals.

What does Bob need?

Bob is being asked to report on a number of farm activities including farm environmental attributes, animal data, health and safety updates and resource management to various entities including industry, local government and central government. The data is in various places and Bob is not fully across all the data himself, let alone in a position to share it.

Bob needs help.

How a data manager can help Bob

Bob has an initial meeting with his data manager who understands all the regional and national requirements Bob has to meet with his data.

The data manager conducts an audit of Bob's current online and written systems. The data manager provides Bob with a list of actions he needs to take and explains what will happen with the data. The data manager then sets up an account for Bob so all his data is collected in a data lake and is permissioned to go out to various reporting systems.

The data manager provides Bob with some recommendations on how to speed up some of his data capture. The data manager also checks with Bob on what data he wants to receive back.

A plan is created for Bob and an annual review takes place to refresh the plan. This is the most basic service of the data manager – to maintain farming operations.

Mary - Young innovative farmer

Mary, her husband, and three young children have recently made the shift from share-milking to farm ownership and have managed to purchase their own 350-cow dairy farm. Mary is ambitious and wants the best performance from her farm by balancing the environmental, economic, and social aspects of the farm.

Mary cares deeply about her herd and wants to maximise the performance of her animals and maintain the most productive dairy cow animals.

Mary and her family have taken on a significant amount of debt to be able to purchase the dairy farm and need a plan to reduce this debt as quickly as possible, while meeting regulations and maximising performance.

What does Mary need?

Mary needs to be able to gather intelligence and information on her farm that she can make decisions from. Meeting regulations is the most basic step for Mary, what she really needs is her data shared back to her in a holistic view that she is able to make decisions and trade-offs from.

Mary is a visual person and needs to see trends and production attributes, she does not like reading reports.

How a data manager can help Mary

Mary goes to an initial meeting with her data manager who asks her questions to determine what Mary wants from her data.

The data manager will conduct an audit of Mary's current data systems and understand where different pieces of data are sitting, they will then explain to Mary how the data will be extracted from those systems and held in a data lake managed by the data manager. Some systems may have APIs that can be used to extract the data, others will need to be data mined. The data manager will seek permission from Mary on the access to systems and use of data.

Once the data is sitting in a data lake there are many possibilities and analytical tools that can be put across the data. Mary has the opportunity to see the data in different farm management software solutions or a bespoke PowerBI report can be created by the data manager. Depending how Mary wants to see the information and what is the most cost effective solution for her.

Mary's main driver for the farm is optimising herd performance so the data manager will recommend some solutions for herd management software explaining how they work and what they can provide for Mary.

Mary will also receive a weekly report summarising herd performance, environmental performance and farm performance and which areas need to be looked at from a risk perspective. Mary meets with her data manager biannually to ensure her requirements are being met and the systems are still fit for purpose.

Tane - Environmental Māori farmer

Tane is the farm manager on a large Māori land block that is mainly hill country with many water ways running through the property. Tane is very conscious on the environmental aspects of the farm and is actively fencing off water-ways and undertaking riparian planting.

Tane wants to better track how the environmental initiatives are impacting on production, animal welfare, and land performance.

What does Tane need?

Most Māori land is administered by trustees or management committees. Much Māori agricultural production is carried out by corporate farmers – landowners do not work on farms but employ others, like Tane, to run them.

Land provides owners with their tūrangawaewae (their place to stand, or sense of belonging). The land is precious, and therefore owners are often multi-generational planners, a 100 year plan is not unheard of. Any changes that Tane makes he needs the approval of his Trust and needs to convince it of the benefit of what he is doing on the land.

How a data manager can help Tane

A data manager can assist Tane in sharing the land story and inform decision-making and strategic planning for the Trust.

Tane will sit down with the data manager and explain why he is farming the land and what is important to him and his Trust. The data manager will develop a strategy and plan for how Tane and his Trust can best achieve the outcomes and objectives they have for the land.

The data manager will help Tane with what data collection is required on the land to meet regulations. Once Tane and the data manager have a plan of what data is required and what data is best practice to enable them to achieve the strategy, both of them will present to the Trust. This is an important step to ensure the Trust agrees with the approach and supports the strategy. Some investment into data collection tools may be required and for the Trust to agree to this it needs to understand the intention of this and how it helps the Trust to achieve its outcomes and objectives for the land.

Tane will then report to the Trust on a regular basis of how the farm is performing using the visualisations and tools suggested by the data manager. Tane will meet with his data manager biannually to ensure what he is doing remains fit for purpose.

Andrew - Corporate farmer

Andrew started farming on his family farm and learnt the ropes of the trade from his family by doing. Andrew has taken over the family farm and has a Bachelor of Agriculture. Andrew is mid-level in his career and he has a number of interests in other properties. Currently his portfolio sits as:

- 700-cow family dairy farm – full ownership
- Neighbours' mixed dairy and crop farm – 50% ownership with the neighbour
- Run-off property 40 kilometres away – ownership split unequally four ways and Andrew has a 20% share

Andrew is interested in the performance attributes of each of the properties. He wants to be able to compare them and understand each of the financial and environmental management controls on the properties. The biggest challenge is there are a number of different data systems across the properties as the suppliers are all different. Andrew is not able to determine the systems for each property alone. This means Andrew's biggest challenge is the number of locations and systems where the data is held before considering the interoperability of the data.

Andrew does not know where to start.

What does Andrew need?

Andrew needs a centralised solution that pulls all the data from various places into one location so it can be analysed and reviewed for performance measures. Right now Andrew is finding it difficult to see everything in one place and is relying on excel spreadsheets to match the various data points and systems to be able to see a full picture of his farming interests.

Andrew needs a way to capture the data that allows him to undertake analysis over it. Andrew does not own all of the data that he requires, some is joint ownership so he also requires agreements from the other interested parties to collect, hold, and analyse the data.

How a data manager can help Andrew

A data manager will sit down with Andrew to first understand his strategy and need for the data. The data manager will then meet with each of the property managers from Andrew's farms to map the data locations and what is held where. Once this is completed the data manager can conduct a data audit to check what data Andrew is able to capture and if there are any gaps.

From here the data manager may recommend any additional data collection tools Andrew may need and explain the costs and benefits of them. The data manager will then work with the system support teams (with Andrew's permission) to access APIs to pull the data from the system and for those that do not have this capability, encourage them to create an API or data mine the system.

Once all the data is collected in a data lake the data manager will be able to run a transformation tool across the data. From here bespoke PowerBI dashboards and reports can be created for Andrew on the variables and aspects he would like to see. Andrew then meets with the data manager biannually as he is interested on staying on top of the insights and understanding where he can get better and richer data to enable him to make better decisions on his farms and investments. Andre shares all the outputs with his co-owners so he can explain the benefit of data capture and analysis to them.

Conclusion

This report has explained the importance of data interoperability on farm to meet the growing consumer requirements of providing evidence to claims being made.

Data interoperability is not easy. If it was it would have been fixed already, the key is the relationships and trust built between companies and entities that support farming. We need to come together as an industry to prove our claims to the growing negative farming rhetoric coming from non-farming consumers. Hence the creation of the #letsdothistogether. No single entity can do this alone, just as a farm is not an island.

The report went through a number of case studies discussing different solutions being used overseas and their outcome. This then led to the very important point that we are not expecting farmers to be experts in accounting and finance so why are we trying to target farmers with data management? This needs to be a discipline in itself to support the farmer or grower and work directly with them on their data strategy and then implement it. All farmers and growers are different and have different drivers for being in the business and hence they need a bespoke solution that gives them what they need.

If every farming centre in New Zealand has access to farm data managers that have a portfolio of farmers and growers they are working with, we could get something really powerful. New Zealand is the ideal testing ground for this because we are an innovative and nimble society. We need to try something different and this could be an alternative path forward on addressing data interoperability on farm.

#Letsdothistogether

Reference List

(2022) *Global Partnership for Sustainable Development Data*. Available at: https://www.data4sdgs.org/index.php/ (Accessed: December 29, 2022).

Agritech NZ (2022) *2022 Baseline of Digital Adoption in Primary Industries*. rep. Agritech NZ.

Carbonell, I.M. (2016) *The ethics of Big Data in big agriculture, Internet Policy Review*. Available at: https://policyreview.info/articles/analysis/ethics-big-data-big-agriculture (Accessed: January 21, 2023).

Chambers (2008) *Farming - an introduction: The farming system, Farming - An Introduction: The Farming System*. Available at: http://geobytesgcse.blogspot.com/2008/04/farming-introduction-farming-system.html?m=1 (Accessed: February 18, 2023).

Chatzikostas, G. (2022) *Fair and powerful data economy for Sustainable Food Systems: Project DATA4FOOD2030, DjustConnect*. Available at: https://www.djustconnect.be/en/fair-and-powerful-data-economy-sustainable-food-systems-project-data4food2030 (Accessed: January 21, 2023).

Concept note - High-Level Event on Unlocking Impact: Data with Purpose (2022). 77th Session of the United Nations General Assembly. Available at: https://static1.squarespace.com/static/62669c6628ceed259712c4dd/t/632470e897d83572df9f1955/1663332584623/Concept_Note_2022-UNGA_Data-with-Purpose_V15.pdf (Accessed: December 28, 2022).

Data with purpose (2022) *Unlocking Impact: Data With Purpose*. Available at: https://datawithpurpose.org/ (Accessed: December 29, 2022).

FarmHack.nl International (2019) *FarmHack*. Available at: https://www.farmhack.nl/en/ (Accessed: December 31, 2022).

Francis, T. and Hoefel, F. (2022) *'true gen': Generation Z and its implications for companies, McKinsey & Company*. McKinsey & Company. Available at: https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/true-gen-generation-z-and-its-implications-for-companies (Accessed: January 19, 2023).

GRAIN (2021) *Digital Control: How Big Tech moves into food and farming (and what it means)*. GRAIN. Available at: https://grain.org/en/article/6595-digital-control-how-big-tech-moves-into-food-and-farming-and-what-it-means (Accessed: February 5, 2023).

Hawes, T. and Ball, C.J. (2021) *Overview of APIs: Value, benefits, and how to avoid vulnerabilities, Overview of APIs: Value, Benefits, and Weaknesses*. Available at: https://www.mossadams.com/articles/2021/09/how-an-api-works (Accessed: January 22, 2023).

Henriyadi, H. (2021) "The model of data interoperability in farm management information system," *18th International Semantic Web Conference (ISWC), Auckland New Zealand* [Preprint].

Reference List

Javaid, S. (2022) *Data Interoperability & Machine Learning in 2023 & beyond, AI Multiple*. Available at: https://research.aimultiple.com/data-interoperability/ (Accessed: December 29, 2022).

Lehne, M. *et al.* (2019) "Why Digital Medicine depends on interoperability," *npj Digital Medicine*, 2(1). Available at: https://doi.org/10.1038/s41746-019-0158-1.

Lizardo, O. (2021) *Consciousness and schema transposition, Culture, Cognition, and Action (culturecog)*. Available at: https://culturecog.blog/2021/11/02/consciousness-and-schema-transposition/ (Accessed: January 4, 2023).

Medlicott, A. (2022) *Developing with business capability APIs: Pros & Cons, digitalML*. Available at: https://www.digitalml.com/pros-cons-developing-business-capability-apis/ (Accessed: January 22, 2023).

Noura, M., Atiquzzaman, M. and Gaedke, M. (2018) "Interoperability in internet of things: Taxonomies and open challenges," *Mobile Networks and Applications*, 24(3), pp. 796–809. Available at: https://doi.org/10.1007/s11036-018-1089-9.

Perriam, J., Birkbak, A. and Freeman, A. (2019) "Digital Methods in a post-API environment," *International Journal of Social Research Methodology*, 23(3), pp. 277–290. Available at: https://doi.org/10.1080/13645579.2019.1682840.

Powering up innovation through trusted data (2022) *PureFarming*. Available at: https://www.purefarming.com/ (Accessed: January 21, 2023).

Standards and data exchange in Agriculture (2021) *Aspexit*. Available at: https://www.aspexit.com/standards-and-data-exchange-in-agriculture/ (Accessed: December 30, 2022).

Talend (2023) *Data Lake VS Data Warehouse: Key differences, Talend*. Available at: https://www.talend.com/resources/data-lake-vs-data-warehouse/ (Accessed: January 23, 2023).

Voyado Lund (2022) *Generation Z: Online shopping habits and behaviour [2022], Generation Z: Online Shopping Habits and Behaviour [2022]*. Voyado Lund. Available at: https://www.apptus.com/blog/generation-z-online-shopping-habits/ (Accessed: January 19, 2023).

Zeng, M.L. (2019) "Interoperability," *Knowledge Organization*, 46(2), pp. 122–146. Available at: https://www.isko.org/cyclo/interoperability#5.1.

Zqrx: Regenerative wool (2023) *Discover ZQ*. Available at: https://www.discoverzq.com/zqrx (Accessed: January 19, 2023).

Nuffield New Zealand

#LETSDOTHISTOGETHER