Farm Foundation
Accelerating people & ideas

Building trust and understanding at the intersection of agriculture and society.

ISSUE REPORT

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Data Interoperability in Agriculture

Interoperability is the ability to exchange and make use of data between devices and systems.

Interoperable data is all around us—we seamlessly share data across different computers and mobile phones to shop online, navigate streets, share pictures, stream videos, make payments, calendar events, and track our health and wellness. But not long ago, it was not possible to share a Microsoft Word document to an Apple computer, easily display websites on any browser, use your bank card at any ATM, or even send a text message across different wireless carriers.

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About this Issue Report

This Farm Foundation Issue Report provides a high-level overview of data interoperability and its role in creating a productive, resilient, and innovative agriculture system.

> *Digital agriculture is "the use of digital devices to gather, process and analyze spatial (object) or temporal (time) data. This data can then guide targeted actions to improve agricultural efficiency, productivity and sustainability."[1]*

While digital agriculture innovations have enabled data collection at unprecedented scale, the ability to move data between devices and systems remains a sticking point across the industry. As a result, much of the food and agricultural data collected remains in silos, on the farm or separated by organization and industry. The resulting data bottlenecks limit innovation and efficiency throughout the supply chain, contribute to an AgTech environment where many digital solutions have unclear value for adoption, and ultimately obscure the full picture of agriculture's impact and potential. This report introduces the issue of data interoperability in agriculture, assesses possible pathways for data interoperability to be achieved within the industry, and explores why interoperability is vital for a productive, resilient, and innovative food and agriculture system.

Emergence of Interoperability in Industry

New technology breakthroughs, rising consumer demand, changing market or regulatory conditions, and broad recognition of the opportunity to benefit from open, networked solutions have created the environment for interoperability to emerge in many industries. The Universal Product Code (UPC) barcode is one early, groundbreaking example of interoperability. In 1973, a group of grocery industry associations teamed up to develop a way of getting shoppers through stores more quickly.[2] The result? A nearly ubiquitous standard that stimulated innovation and helped digitize supply chains around the world.

In the financial sector, the rise of Open Banking in 2010 enabled the sharing of financial account and payment information across systems via open application programming interfaces (APIs) and open source technology and unleashed a torrent of "fintech" innovations that, to this day, are providing greater consumer choice, more products and services, and greater financial control.

The benefits of interoperability and its applications to agriculture are numerous. At a high level, interoperable data unlocks actionable insights by enabling an integrated view of the whole, connecting once disparate sets of data and illuminating real world interactions and trends. Farmers can leverage interoperable data to optimize resource utilization and improve business, production, and sustainability outcomes. Industry-wide interoperability facilitates a food and agriculture value chain with greater agility, profitability and resilience, improved health and sustainability outcomes, and decreased waste.

Technical, Structural, and Semantic Interoperability

For two systems to interoperate, they must be able to integrate and exchange data with one another and interpret and present that data in a way that can be understood by the other system. First and foremost, the physical infrastructure and protocols must be in place to transport data between devices or systems. Then, common ***data structures and formats***, i.e., structural interoperability, enable the communication and exchange of data between systems. Finally, ***language frameworks***, i.e., semantic interoperability, establish a shared meaning of that data, enabling the systems to understand the information being exchanged.

Establishing the infrastructure for interoperability also includes solving the challenges of data authorization, discovery, identification, retrieval, modification, notification, permissioning, and sharing. This ultimately gives data owners and approved users the ability to get the right data, in the right format, to the right place, at the right time, for the right reasons.

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Data, Technology, and Agriculture

Agriculture has long been a pen and paper profession and today remains one of the least digitized sectors of the U.S. economy (along with government and construction). A recent Trust in Food survey of U.S. farmers found that nearly a third of respondents primarily store and manage their data on paper records, and more than half did not rely on farm-level data software; of the 50% of farmers who do use Farm Management Information Systems (FMIS), less than half were completely satisfied with the software outputs.[3] A key barrier to the digitization of food and agriculture as well as farmer satisfaction with digital solutions is the absence of industry-wide **structural** and **semantic interoperability**.

Structural interoperability ensures that data exchange can be interpreted at the data field level. For example, if a farmer shared data on crop type, production practices, and yield, the receiving device or system would recognize this information as crop type, production practices, and yield data due to a common data structure and format. However, the agriculture industry's default model, pioneered by machinery manufacturers, is to develop and market software and devices in proprietary formats. This has created a situation where thousands of devices and systems operate in their own ecosystem with different data formats and languages. As a result, the industry is full of single point solutions that get data elements from point A to point B, with no standardized way to connect and exchange data between these points.

TECHNICAL INTEROPERABILITY

- **Infrastructure and protocols:** the physical infrastructure is in place to transport bits of data

SYNTACTIC INTEROPERABILITY

- **Common data structure:** the ability to communicate and exchange data between two or more systems through a standardized structure and format; shared syntax

SEMANTIC INTEROPERABILITY

- **Common data definition:** the ability to exchange data between systems and for the data to be understood by each system; shared meaning

Semantic interoperability enables the shared data to be understood so that systems may interpret that data, allowing the data owner or user to make inferences from the data. Semantic interoperability requires consensus on the shared meaning of data, such as farm data (people, place, time, etc.), geographical and climate data, production data, or farming equipment and input data. Today, data definitions may vary by farm, region, or country.

The lack of structural and semantic interoperability limits the choices farmers have in adopting new technologies and creates barriers to efficiency in utilizing software from multiple providers and devices. Farmers must spend time, energy, and resources getting these systems and devices to "talk to each other." Many current technology solutions also lack the ability to easily share information with important partners like certification bodies, buyers, haulers, bankers, or insurers, leading to further manual and repetitive data collection, organization, and sharing.

> *"Users are having to enter data in an app, and then the next app, and then enter it again. In a lot of cases, they're entering the same data multiple times to drive that solution. It's not viable, it's not efficient. When they change one of those data attributes, they have to change it in everything. It's just not functional," says Mark Pawsey, Business Development Director for Proagrica.*[4]

Agriculture's Evolving Operating Context

It has long been standard practice that farmers share some amount of data with those they have direct business relationships with, like processors, distributors, or banks. This basic data sharing has been required for perfunctory reasons such as regulatory requirements or processing payments, which, although inefficient and inconvenient, could largely be conducted via email, manually gathering and sharing PDFs or inputting and re-inputting relevant data into various apps, systems, spreadsheets, etc. as the need arose.

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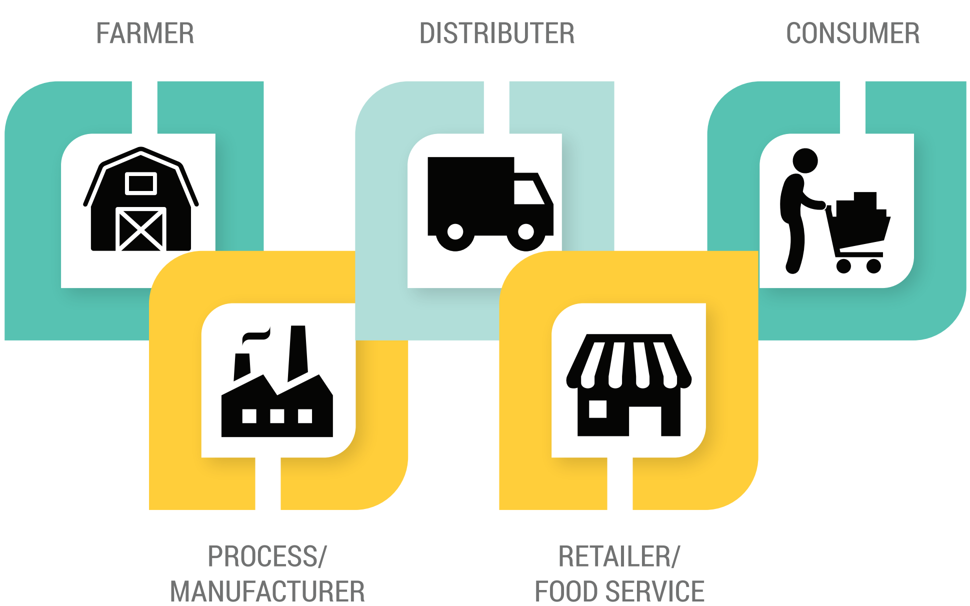
In recent years, calls for certain data to be accessible and shareable throughout the supply chain have grown considerably louder, increasingly taking the form of new regulatory or retail reporting requirements. This call for ***transparency*** has amplified the need for supply chain ***traceability***. Traceability—the ability to follow a product through all steps of the supply chain—is critical to ensuring food safety and quality, but the United States currently "lacks a harmonized system of traceability from farm to fork that is universally understood and utilized. This means… that our ability to rapidly track and trace food is often impeded by insufficient data identifying a food as it moved through its supply chain."[5]

Traceability remains a significant challenge for companies and industry groups across food and agricultural supply chains. A fully integrated, traceable supply chain would provide farmers with better control and insight into where their products head once leaving the farm, shining light on what is currently a black box. When issues like food safety problems arise—at any point in the supply chain—having a seamlessly integrated and traceable digital record for agricultural products can help to pinpoint exactly which products need to be recalled, enabling farmers and supply chain actors to respond more quickly and accurately, reducing the amount of food wasted, money spent or lost, and, most importantly, the overall impact to human health.

Meeting agriculture's high-level goals—food safety and profitability, sustainability and resilience, production of abundant food, fiber, and thriving communities—requires a standardized framework for collecting, organizing, sharing and defining data across the supply chain. As it stands today, farmers face a host of compliance and regulatory challenges, increasingly need the ability to verify industry-specific claims (around animal health, water quality, production practices, labor, etc.), and lack a clear pathway for adapting to this changing regulatory environment; nor can they leverage interoperable data to gain insights and adapt to changing market or climate conditions. Interoperable tools can enable automation and validation, significantly reduce the compliance burden, and improve outcomes across the myriad of areas where food and agriculture have direct and indirect impacts.



Achieving Data Interoperability in Agriculture

On one level, achieving interoperability is a technical challenge: the development of common structures and definitions for sharing data across devices and systems. On another level, it is a social challenge. Interoperability requires multiple parties (with potentially competing interests) to work together to solve a common problem for the common good. At the outset, increased data collection and sharing hinges on cultivating a "business and normative culture among farmers that understands, values and trusts the critical role data collection and sharing play in both their operation's success and that of U.S. agriculture as a whole."[6] Foundational to such a culture of data sharing are solutions providers and policy makers who value and protect farmers' privacy and data rights.

More broadly, success in this space requires a recognition that 1) industry-wide interoperability unlocks benefits across the value chain otherwise inaccessible and these long-term benefits outweigh any short-term benefits of not interoperating, such as an incumbent's proprietary advantage, and 2) successful transformation of the food system requires commitment from industry partners to invest in and champion interoperability initiatives and solutions. As such, interoperability can fundamentally be thought of as an issue of ***trust, collaboration, and data sharing***.

Open source software is code that is designed to be publicly accessible—anyone can see, modify, and distribute the code as they see fit.

OPEN SOURCE CODE IS:

- developed in a decentralized and collaborative way, relying on peer review and community production;
- often cheaper, more flexible, and longer lasting than its proprietary peers because it is developed and maintained by communities rather than a single author or company.

Open source has become a movement and a way of working that reaches beyond software production. The open source movement uses the values and decentralized production model of open source software to find new ways to solve problems in their communities and industries.[7]

Pathways to Interoperability in Agriculture

There is no single or "right" pathway to interoperability. As we look to build (and develop) a food and agricultural system responsive to 21st century challenges and needs, there are lessons to be learned from the sectors that have successfully done this work. In the examples above, individuals intentionally collaborated to solve a shared problem for the benefit of industry—and by extension, all of us. Additionally, many successful interoperability initiatives, such as Open Banking, have been ***open source***.

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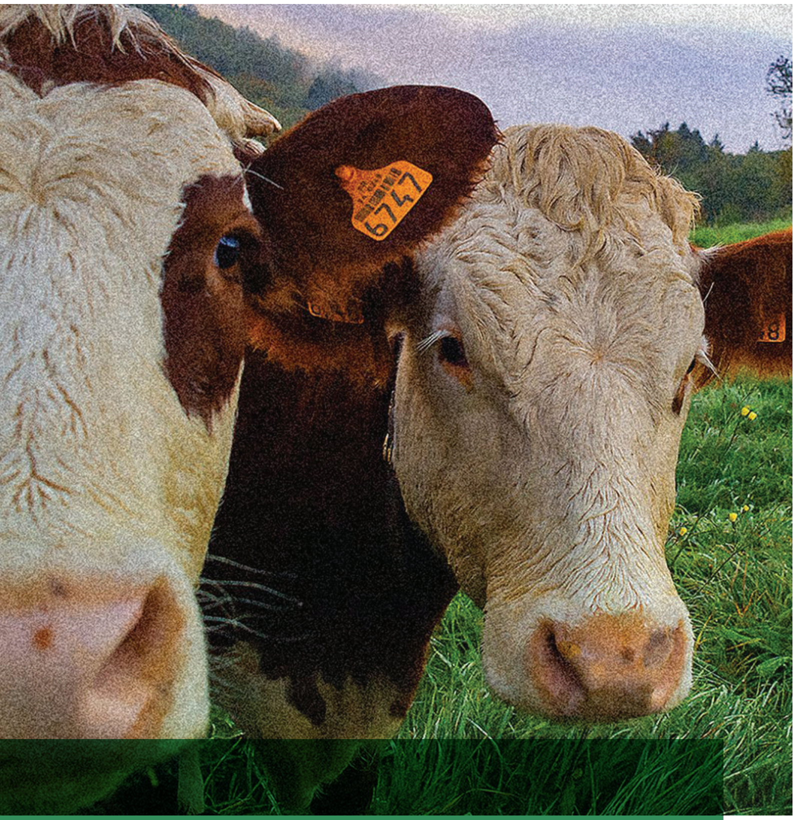
Any pathway to interoperability will have to navigate the divergent needs and capabilities of ecosystem players, disparate protocols, technologies, and standards, fragmented data production and sharing systems,[8] and massive quantities of messy data. Successfully achieving interoperability in agriculture will depend on strengthening two somewhat shaky pillars—rural connectivity and established best practices for agriculture data usage (privacy, sovereignty, and sharing). Looking at the current agricultural data landscape, there are four primary approaches to achieving interoperability: 1) point-to-point integrations, 2) linking systems of systems, 3) formal standardization, and 4) walled garden integrations.



1. Point-to-Point Integrations:

One-off point-to-point integration between applications

Today, interoperability is primarily achieved through individual point-to-point integrations via customized application programming interfaces (APIs). This requires manual alignment and organization of different data formats and systems on the front end to facilitate accurate data exchange and understanding, and often involves massive quantities of data—which means time and/or money spent engineering interoperability and manually re-keying information, either internally or by outsourcing enterprise

2. Linking Systems of Systems:

The development and adoption of open source, commonly used tools and frameworks to connect different systems

Rather than creating custom integrations and connections for each individual system, another method is to develop a framework that enables interoperability with any system (saving significant time and/or money in the process).

There are encouraging efforts underway to create these tools, such as the work of Purdue OATS, Centricity's Trellis framework, AgGateway's ADAPT, CGIAR's GARDIAN, and Leaf, though they are still in the early stages of development or market adoption.

3. Formal Standardization:

The development and adoption of shared, open source frameworks through formal multi-party agreement

Standardization is "the process of developing and implementing specifications based on the consensus of the views of firms, users, interest groups and governments."[9] In theory, standardization is the most effective and powerful tool available to achieve interoperability. However, the development and wide adoption of standards is an extremely difficult process; the larger the system, the more inherent complexity and diversity and, thus, the greater the challenge of achieving consensus among stakeholders.

Further, the process of standardization is traditionally performed in mature industries and systems where the tasks and models are well-established and stable over time. As difficult as that is in and of itself, the difficulty is compounded in an actively-innovating industry, like AgTech, where the landscape of what data is available and how it is used is rapidly progressing and not clearly established. There are cases where de facto standards—such as the QWERTY keyboard—emerge as dominant without a formal standardization process when "a group of people have developed a solution that is sound and timely with respect to a certain requirement." [10]

ISOBUS is an example of a successful worldwide standard in agriculture that enables compatibility and connectivity between tractors, displays, implements, and farm management software (FMS)—regardless of brand. Prior to ISOBUS, every piece of tractor equipment required its own proprietary display, wiring, and communications.

4. "Walled Garden" Integrations:

Proprietary data integrations driven by a large player (or players) not necessarily intended for use beyond their own ecosystem

A walled garden is a closed digital ecosystem. Operators of walled gardens maintain control of their software and information, as well as their users' data, typically with no intention of sharing. Walled gardens emerge, particularly in the early stages of a market, as a way to justify business investments and maximize returns on those investments. They are rooted in the belief that users' data will provide value today and in the future, and sharing that data—either with users or competitors—will give away a portion of that value.

Walled garden data ecosystems can lead to market improvements, such as increased investments in supply chain efficiency and the ability to offer users more tailored products and services. However, there is a real risk that the concentration of too much data in too few platforms managed by a handful of powerful players will stifle competition, innovation, and choice to the detriment of users—in the case of agriculture, farmers—with industry-wide impacts that affect both people and the planet. Users are at risk of vendor lock-in, leading to potentially higher costs or subpar solution sets, and significant data export challenges.

As larger economic actors use their influence to develop their own data ecosystems and platforms, or form alliances and data integrations with other large players for mutual benefit, de facto data standards can emerge. John Deere Operations Center (Ops Center) is an example of a walled garden in agriculture that continues to increase the number of partner application integrations. At the time of writing, 250 partner integrations are available through John Deere Ops Center.

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The Apple iOS, Google Android, and Facebook platforms are notable examples of walled garden data integrations. In each of those examples, applications can leverage the platform's capabilities (like GPS location, in the example of a mobile phone) in exchange for sharing information as well. The largest players—like Google, Apple, or John Deere Ops Center—have developed rules for what platform capabilities can or cannot be leveraged by application providers, what data must be shared or cannot be shared, and under what conditions data can be shared between different applications. Of course, the platform provider needs the consent of users to share data through "user agreements."

It is worth noting that it is possible for walled gardens to be opened. As an example, Amazon Web Services (AWS) started out as the proprietary back-end data platform that powered Amazon.com. AWS has since been spun out as an independent platform available to all with a shared, integrated set of SAAS-based services for customers.

It is also worth noting that many organizations working on this issue, particularly those in academia and in government, appear to be doing "research for researchers" without a clear pathway for translating their findings for practical application in agriculture. There have been many intellectual assets developed by these institutions, notably in the form of burgeoning semantic ontologies (i.e., vocabularies), that remain unused in a real-world setting.

The Path Forward

Agriculture touches every facet of life on earth; how we produce food determines the health of people, the planet, and the economy. It is a necessary endeavor, and an increasingly challenging one. Additional data sharing requirements, the need for real-time actionable insights in an increasingly complex operating environment, and the significant costs of not being interoperable make the need for data interoperability in agriculture both urgent and acute. A critical barrier to industry-wide interoperability continues to be the lack of collaboration, trust, and data sharing throughout the agricultural value chain. Open source interoperability presents an opportunity for the agriculture industry to embrace innovative models of collaboration and innovation for the benefit of the many, rather than the few.

Interoperability is a prerequisite for large-scale, cross-boundary, cross-system data sharing—the necessary infrastructure of a traceable, sustainable, and innovative 21st century supply chain.

The story of technology in agriculture today is one of two seemingly contradictory truths: rapid innovation and low adoption. It can seem as if technology providers are designing for the future—visions of near total automation, decision support tools with near perfect accuracy, a world with access to endless,

"Agriculture is a shared human endeavor and global collaboration is necessary to translate our available knowledge into solutions that work on the ground necessary to adapt and mitigate climate change, improve livelihoods, and biodiversity as well as the produc[tion] of abundant food, fiber and energy."— Dr. Dorn Cox, project lead and founder of Open Technology Ecosystem for Agricultural Management and research director for Wolfe's Neck Center for Agriculture & the Environment.

connected high quality datasets—while disconnected from the present, sometimes without a basic understanding of agriculture, the needs of farmers, or the very real barriers to adoption, such as limited rural connectivity and limited farmer time and resources. While this type of vision for the future has its merits, we also need practical pathways to get us from ***here*** to ***there***.

Whatever the path forward, global, national, and regional non-profits, government agencies, ag-focused academic institutions, commodity associations, industry associations and even farmer-led interest groups need to be organized around the need for interoperable data solutions that will support farmers and value chain partners to meet the challenges of this century. A targeted effort—one that specifically focuses on enabling real-world interoperability—should be made to translate the good work that has been done, by researchers and others, to address economic, environmental, and societal needs for interoperability in agriculture.

It may not be easy, but with the right focus and commitment, data interoperability in agriculture can be achieved, with the fruits of industry-wide transformation continually realized well into the future.

ENDNOTES

[1] https://ag.purdue.edu/digitalag/

[2] https://www.smithsonianmag.com/innovation/history-bar-code-180956704/

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[8] https://unstats.un.org/capacity-building/meetings/UNSD-DFID-SDG-Open-Data-Bangladesh/documents/Day-2-Interoperability.pdf

[9] https://www.sciencedirect.com/science/article/pii/S0166497215000929?via%3Dihub

[10] https://www.researchgate.net/publication/251237439_Data_Interoperability