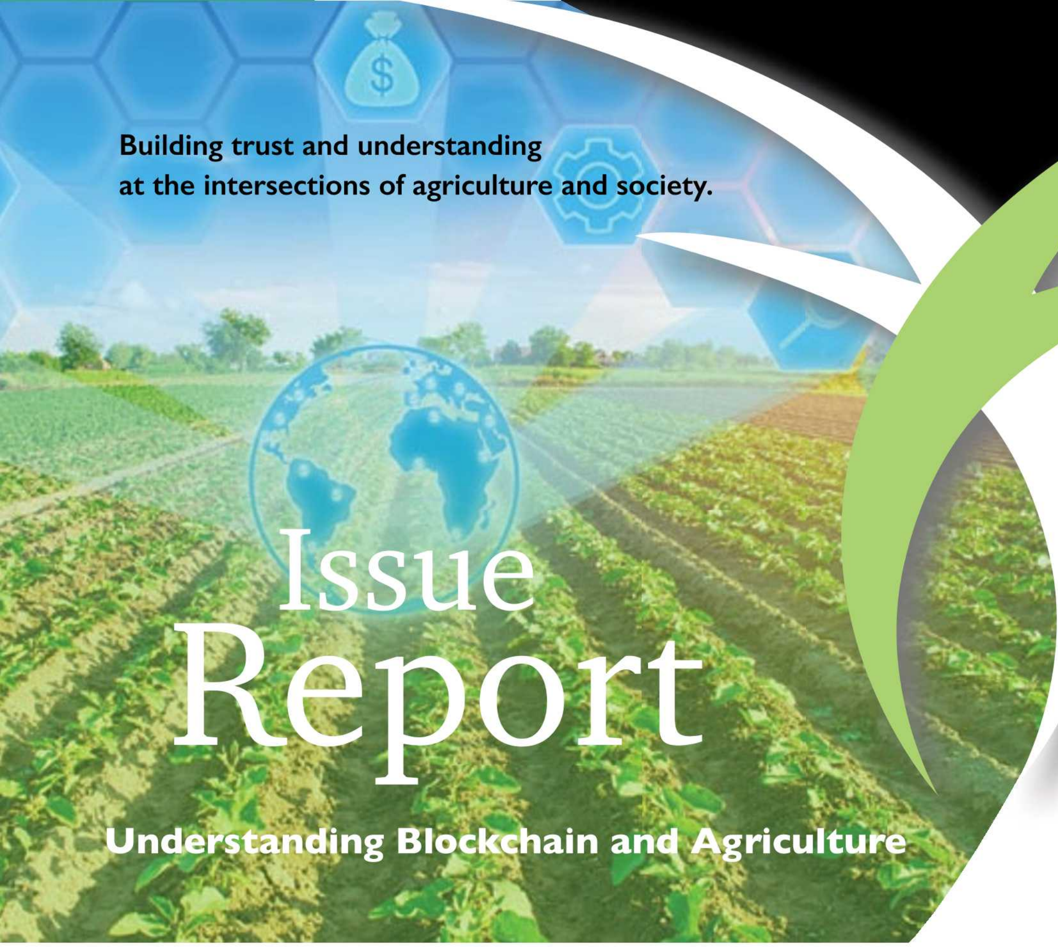

Building trust and understanding
at the intersections of agriculture and society.

Issue Report

Understanding Blockchain and Agriculture

By Daniella Taveau and Andrew Platt

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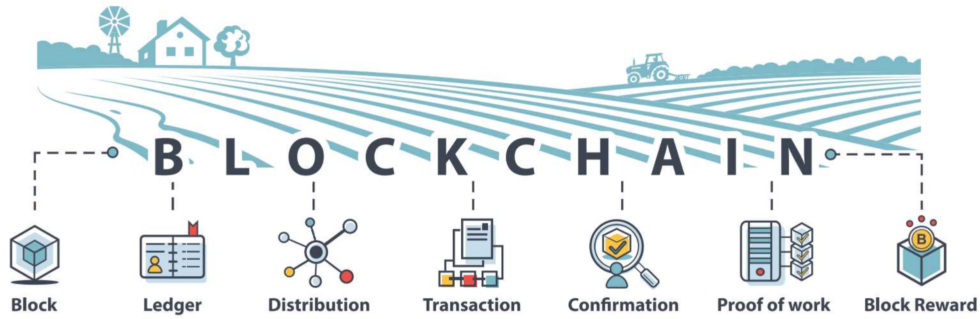
Farm Foundation®

About this Issue Report:
This Farm Foundation Issue Report provides a high-level overview of blockchain technology, in order to better understand how blockchain technology works and how it might be applied to the food and agricultural sector.

What is Blockchain and How Does It Differ from Bitcoin?

The U.S. National Institute for Standards (NIST) defines blockchain as "tamper evident and tamper resistant digital ledgers implemented in a distributed fashion (i.e., without a central repository) and usually without a central authority (i.e., a bank, company, or government)." At their basic level, they enable a community of users to record transactions in a shared ledger within that community, such that under normal operation of the blockchain network no transaction can be changed once published.

Bitcoin is perhaps the most prominent example of blockchain; however, its spectacular rise and fall has very little to do with the underlying power and application of blockchain technology. Bitcoin, itself, is not blockchain, but rather a digital currency running on a blockchain network.

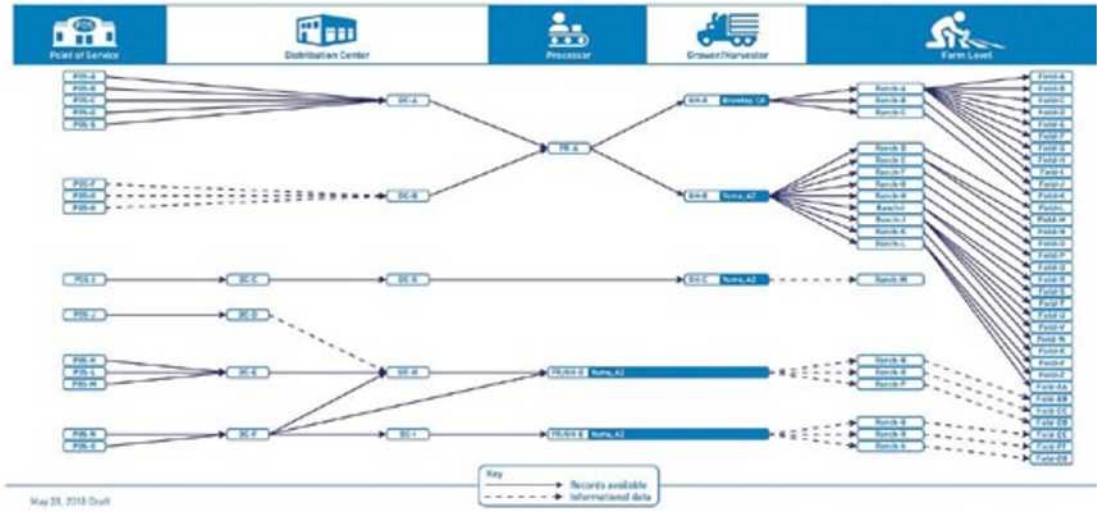


Making the Case for a Modern System of Traceability

In early March 2018, people across several Western states started falling ill with a virulent strain of *e. coli.* The U.S. Food and Drug Administration (FDA) became aware of the problem on April 4, 2018 and made a public announcement on the April 10 that it suspected the cause was romaine lettuce. By mid-April, using the full authority of the Agency, FDA had only been able to narrow down the suspected origin to the general region of southern Arizona. Supermarkets across the nation pulled all leafy greens from their shelves. By the end of May, the FDA was able to identify the origin of the tainted romaine as generally from the region of Yuma, Arizona, but still was not able to pinpoint the farm or farms responsible. It was not until the end of June that the FDA determined the culprit was a 3.5-mile irrigation canal used by only 23 farms. During this four-month period, over 96 people were hospitalized and tragically five died as a result of the outbreak. For farmers, the economic cost was devastating. In addition to the ban on romaine sales during the outbreak, there was a 45% drop in demand for *all* leafy greens for months following the outbreak.

Why did it take so long to isolate the problem? The current system for food traceability is built around the GS1 standard, where individuals keep purchase and sales records. (See Figure A.) There are no requirements to share data, or even keep transaction records in electronic form. This means when the FDA began its traceback, it had to start with the sickened individual, then the store, then the distributor, and so on, back up the food chain. This can take days or weeks of resource-intensive research and site-visits. The diagram below demonstrates the complexity of the problem.

Figure A. Sample Traceback Program for FDA Investigation



To address this problem, the FDA is using its authority under the Food Safety Modernization Act (FSMA) to implement new technologies and processes, including blockchain, to simplify and speed up this traceback process. In its simplest form, blockchain is a secured common record of transactions, the most up-to-date version of a ledger.

Frank Yiannis, Deputy Commissioner for Food Policy and Response at FDA, created a blockchain based traceability system for food in his prior role as Vice President of Food Safety at Walmart. Internationally, blockchain traceability is being piloted or used in Australia for beef; in China for pork, dairy, and grains; and in Africa for coffee and cassava. The European Union is looking to use blockchain for food safety and food fraud. Major companies including Cargill, Bayer Crop Science, Tyson Foods, and John Deere are all involved in blockchain projects.

Let's consider a field of soybeans – from seed to fork – where each stage of the process involves a transaction between parties. A farmer buys seed and plants it; it grows and the farmer sells it to a collective that stores it in an elevator; then, it's sold to a feed company, shipped by rail to a processing plant, and turned into 50-lb sacks and sold to a rancher. If the rancher discovers a problem, the authorities must forensically trace the problem to its origin in the supply chain, using resource-intensive investigative methods. Contrast this antiquated method of chasing four different sets of ledgers with implementing modern blockchain. If each transaction were put into a single tamper-proof database, that trace would take seconds rather than days or weeks, and would look something like this:

Figure B. Sample Blockchain Ledger

	Grain In	Grain Out
Farmer A		3 Tons
Silo B	3 Tons	3 Tons
Railway C	3 Tons	3 Tons
Mill D	3 Tons	

How Does Blockchain Remain Secure?

The first step of blockchain security is the concept of *triple entry bookkeeping.* (See Figure C.) For a transaction to post to the blockchain both sides must *agree* that said transaction occurred.

Figure C. Sample Triple Entry Accounting

Alice's Books		Bob's Books		Public Book	
Debit	Credit	Debit	Credit	Alice	Bob
5			5	-5	5
	2	2		2	-2
	9	9		9	-9
10			10	-10	10

Looking at the ledger above (Figure B), if Farmer A sells 3 tons of wheat to Silo B; Farmer A would report 3 tons sent to Silo B and Silo B would report 3 tons received from Famer A. The underlying computer code of the system, that is developed to be unbreakable, prevents Silo B from creating the soybeans from thin air or Farmer A from reporting a transfer of 6 tons if Silo B reports 3 tons.

The second step to ensure blockchain's security involves encryption and *interlocking.* The database in which the entries are made aggregates all the transactions every few minutes into a *block* of data. Using encryption this block is distilled to a unique I.D. value, and that unique I.D. is added to the transactions in the next *block* of data. If any transaction in a *block* is changed, then the unique I.D. changes. Because each *block* is *chained* and *interlocking* to the *block* above and below it, if someone were to attempt to change even a single transaction, he or she would have to break the encryption not just of that *block* but all subsequent *interlocking blocks* as well.

The third and final stage of blockchain security is *duplication.* Using the internet cloud, multiple copies of the ledger are maintained simultaneously on multiple servers. If a malicious actor attempts to modify the transaction record, he or she would not only need to break the encryption in a single *block* and down an entire *chain,* but also to achieve this exploit in real-time across multiple *chains* at once.

How is Blockchain Different from a Database?

A conventional database allows easy collaboration between users. While there may be different permission levels, users with "write" and "edit" access are able to modify any entry in the data set. To ensure data integrity, access to the data is controlled and only a few "super-users" have the permissions to change swaths of data. However, any one of these super-users could, without the consent of the other users, unilaterally change the data itself or even the rules of the database. To protect the integrity of the data in a database, companies often *silo* their data with limits on access and use. Elaborate technical bridges are required to share data between databases and between companies.

In a blockchain, because each transaction is linked to the transaction before it, it is impossible to insert, delete, or modify data without taking apart the entire chain of data. Changes can only be made when a majority of the stakeholders (51%) have achieved consensus on a transaction and those changes would need to occur simultaneously. With this layer of data integrity/assurance blockchains can be transparent to the public, without worries of hackers tampering with them. For a food based blockchain, allowing the end consumer visibility from farm to fork is a key selling point.

The Problems of Blockchain

The same features that make a blockchain ledger so hard to cheat, also hinder its adoption. For this reason, many of the "blockchain" projects on the market today are not true blockchain, but at best a hybrid database/blockchain or even just a database with additional security features.

It's important to understand the difference between *true* blockchain and hybrid versions. A *true* blockchain has its data hosted on many servers called *nodes.* A key security feature in the code is that 51% of the servers must agree on the "truth" for it to be written as the next string of blocks on the chain. In a network of 500, or even better 5000 nodes, it would be very difficult for a malicious actor to take control of the entire system. Many of the popular options to create food trust on a blockchain utilize very few nodes, in some cases less than 10 for the entire network.

A second feature of a *true* blockchain is its permanent record. Because every block is dependent on the block before it, the entire history of the transaction is retained. However, for legal reasons related to data privacy laws, it might not be wise to retain data for years or decades. Some hybridized versions of blockchain address this problem by having very few nodes and having the majority of the nodes controlled by a few actors. They periodically move data "off-chain" and into a database where it can be deleted. This may be good data hygiene but is not a *true* blockchain.

One drawback of a *true* blockchain is its cumbersome speed and energy intensive nature. In order to engage in the blockchain encryption process, computers use a massive amount of electricity to "crunch" the numbers. The process is slow and time intensive. On the Ethereum blockchain a new block is formed once every few minutes and contains about as much data as an average Excel file. To achieve enterprise scale, many industry initiatives sacrifice the security of a true blockchain to achieve the speed and scale needed for agricultural data.

For the end user, it is important to understand what is being offered as "blockchain." If the project is run by a few large multi-nationals and has very few nodes, if data can expire or be "corrected", and if there is limited transparency—the project may be a distributed ledger but is not a "blockchain" solution.

Blockchain and Agriculture

Agriculture has become more mechanized, more consolidated, and more technical over the past 30 years. To compete on a global scale, farmers must be experts in everything from satellite communications and cloud computing to regulations and international trade. As technology continues to grow by leaps and bounds, the terms artificial intelligence (AI) vis-a-vis machine learning and deep learning, operational technology (OT), internet of things (IoT), and blockchain are now being mentioned frequently in relation to agriculture.

In tandem with the rapid growth of technology, consumers are demanding more information about their food – on everything from its production methods to its carbon footprint. Increasingly complex and networked farm equipment produce volumes of data. Identity-preserved crops are becoming increasingly common and governments increasingly regulate food both for trade and safety reasons.

While blockchain can provide an effective solution for traceability and food safety, it also is able to address an important marketplace demand. Globally, consumers are demanding to know the origin of their food. This need can range from Chinese markets where there tends to be a low trust of domestic produce to the European Union and United States where consumers tend to focus on carbon footprint and organic origin. Without end-to-end transparency, farmers who grow organic produce are at the mercy of the supply chain to ensure their food arrives at the market untampered.

In the United States, many seeds are covered by licensing agreements, and farmers are required to show a continuous chain of custody from seed to final harvest. In the European Union, cross-contamination between GM and non-GM products can result in the rejection of an entire cargo. In an opaque supply chain, it is difficult, if not impossible, to determine when and where the fault lies. Organic or appellation certifications are complicated to maintain as a product moves down the supply chain.

The current GS1 standard of "one step up, one step back" was created in an era of paper records and much lower transaction volumes. Global trade now allows a cargo of Iowa soybeans to arrive in multiple overseas destinations, each governed by different regulatory regimes. The FDA under its "Smarter Food Safety" program is using its authority from FMSA to investigate and then mandate the use of new technologies, including blockchain, to increase food supply chain transparency for safety. The United States Department of Agriculture (USDA) has begun certifying blockchain-based technology for traceability as part of its Process Verified Partner (PVP) program. The European Union and several of its Member States are exploring blockchain-based traceability solutions for agriculture.

Blockchain Tracking Projects

There are several companies and projects currently testing or using blockchain to trace food. In the United States, major companies like Cargill, Tyson, and Walmart are all using blockchain for field to consumer applications. A consortium formed by ADM, Cargill, Bunge and Dreyfus is pursuing blockchain together for their sector. A number of smaller producers are using blockchain for end-to-end traceability as a product differentiator. In the US, partnerships are springing up between leafy greens, vegetable, and beef producers with retailers using blockchain primarily for traceability, such as HEB and Walmart. In China, industry leaders like JD.com down to startups like Beefledger are providing supply chain security using blockchain. IBM has developed the Food Trust platform to provide blockchain services to a variety of companies worldwide. There are also many startups that are developing blockchain solutions for agriculture including Agridigital, BanQu, HerdX, Bext360 and Agralogics.

For the last three Thanksgivings, Cargill has partnered with HEB grocery stores to sell its Honeysuckle White turkeys with blockchain tracking from turkey farm to consumer. A customer in an HEB store can scan a QR code on the bird of their choice and see its supply chain history from turkey farm, to processor, to store.

Walmart has been a pioneer in the space, developing the Food Trust blockchain in conjunction with IBM. As an initial pilot they were able to reduce the time to trace Ecuadorian mangos from six days under GS1 to six seconds using blockchain. Most of the other major food producers and grocers including Tysons, Nestle, Albertsons, Smithfield, and Carrefour are working with IBM and others on blockchain-based tracking pilots.

In addition to the major companies, there are a diversity of artisanal U.S. producers using blockchain technology as a consumer confidence tool. The Grass Roots Co-Op in Arkansas grows organic open-range chickens. They use a blockchain trace like Cargill's to allow end purchasers across the southeast to verify cold chain and origin of their chicken. In a more elaborate system Ripe.io worked with tomato farmers and SweetGreen to not only secure the supply chain, but also to provide real-time feedback to the tomato growers as to the quality of their produce. Chai Wine Vault works with high-end vintners and vineyards to provide provenance and brand assurance to small batch wine production.

Outside the United States, China has been a major investor in agricultural blockchain. With a prevalence of food fraud, Chinese consumers pay a premium for non-Chinese agricultural products. The Australian company Beefchain is using blockchain to create supply chain visibility for Australian beef exports to China.

Similarly, Agridigital is working with Australian grain, milk, and lamb producers to secure and make visible their supply chain. Within China, JD.com has created a "porkchain" to ensure cold chain custody and security of its pork suppliers. Bright Food, the second-largest China-based food manufacturing company, is using blockchain to secure its milk supply chain, in light of the 2008 melamine contamination scandal in which thousands of children and pets were poisoned.

There are many other companies creating and deploying blockchain for agricultural solutions. One of the major focuses is in empowering farmers, especially in developing markets. For example, BanQu has partnered with Anheuser-Busch/InBev to work with cassava farmers and ensure they receive full payment for their produce. HerdX in Texas is working with several major ranches to verify authenticity and create visible supply chains for premium beef bound. Bext360 and several premium coffee companies are working together to create sustainable coffee supply chains.

What's Next for Blockchain?

It's not inconceivable that as blockchain proves itself as an effective tool in the fight against contamination, companies and countries alike will require its implementation along the food supply chain. But before blockchain standards and regulations are put in place, are there any potential pitfalls of which stakeholders should be aware? Trent Teyema, former FBI Chief of Cyber Readiness and currently Head of Cyber Threat Management at insurance giant AIG offers the following advice: "In order for blockchain to work it needs to be easy to implement, cost-effective, and adopted on a wide-scale. If a system is not adopted by all parties involved in a transaction, then it will fail. Once blockchain is implemented, especially in the agricultural industry, it will increase efficiencies, reduce food waste, increase profit margins, and most importantly dramatically improve food safety."

[1.] Yaga, D., Mell, P., Roby, N., & Scarfone, K. (2018, October). Blockchain Technology Overview. Retrieved 2019, from https://nvlpubs.nist.gov/nistpubs/ir/2018/NIST.IR.8202.pdf.

[2.] See https://www.gs1.org/standards for additional information.

[3.] https://www.fda.gov/news-events/fda-voices-perspectives-fda-leadership-and-experts/fda-update-traceback-related-e-coli-o157h7-outbreak-linked-romaine-lettuce

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