Research Article

Blockchain in Agriculture

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A B S T R A C T :

The blockchain is a ledger of accounts and transactions that are written and stored by all participants. It refers to a digitized platform that stores and verifies transactions between users of a system. The technology offers a reliable approach of tracing transactions between anonymous participants, thereby quickly detecting fraud and malfunctions. Several companies and government agencies are experimenting with the promising technology. Blockchain has different uses in the agricultural industry such as providing solutions to food safety, food waste, food fraud, supply chain visibility, and management.

Several farmers and agribusinesses have started introducing blockchain technology in agriculture. This article examines the applications of blockchain technology in agriculture and discusses the opportunities and challenges of blockchain.

Introduction

Agriculture is the production of food, fiber, and data. It has played a crucial role in the promotion of life and wellbeing around the world. The sector is crucial to global prosperity. The well-being of every nation is depends greatly on agriculture. Only few industries have a greater impact than agriculture. However, ag-

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riculture faces challenges of food security, food safety, sustainable development, rapidly increasing world population, consumer demand for more information and greater transparency, urbanization, and globalization. To adapt to these challenges, the agricultural sector needs to undergo technological transformation: [1]

- satisfy the demands of a growing population for more high-quality food
- advance technological solutions to meet changing consumer needs
- encourage sustainable agricultural practices and lower environmental
- decrease agricultural supply chain costs
- establish and follow firm sanitary and phytosanitary standards
- sustain profitable operations of farmlands and agribusinesses
- increase the incomes of small farms, private farmers, and food producers.

Today, consumers want to know exactly where their food comes from. This has resulted in agribusinesses searching for supply chain management software to improve food safety, and the traceability of the whole farming supply chain.

Finance was the first sector to which blockchain (BC) technology was applied. In December 2016, the company AgriDigital successfully executed the world's first sale of 23.46 tons of grain on a blockchain. It is currently used in many other areas such as healthcare, smart cities, smart contracts, energy markets, and government sector.[2] The blockchain, when combined with big data technology, can allow multiple parties to interact cooperatively. It can help city government achieve their digital economy goals while ensuring maximum network security.

Overview of blockchain

The term "blockchain" refers to the way BC stores transaction data – in "blocks" that are linked together to form a "chain." The chain grows as the number of transactions increases. Since every entry is stored as a block on a chain, the care you receive is added to your personal ledger.

At its core, blockchain is a distributed system recording and storing transaction records. In a blockchain system, there is no central authority. Instead, transaction records are stored and distributed across all network participants. Rather than having a centrally located database that manages records, the database is distributed to the networks and transactions are kept secure via cryptography. BC eliminates the need for a middleman that traditionally facilitates such transactions. Unlike traditional trading systems, no intermediary is needed to track the exchange; all parties deal directly with each other.[3]

The blockchain was designed so transactions are immutable, i.e. they cannot be deleted. Thus, blockchains are secure and meddle-free by design. Data can be distributed, but not copied. When it comes to digital assets and transactions, you can put almost anything on a blockchain. Different scenarios call for different blockchains.

The BC technology currently has the following features: [4, 5]

1. *Peer-to-Peer (P2P) Network:* The first requirement of BC is a network, an infrastructure shared by multiple parties. This can be a LAN at a small scale or the Internet at a large scale. All nodes participating in a BC are connected in a decentralized P2P network. Transactions are broadcast to the P2P network. Due to some limitations of P2P networks, some vendors have provided cloud-based BCs.

2. *Cascaded Encryption*: A BC uses encryption to protect transaction data. Blocks are encrypted in a cascaded manner, i.e. the encryption result of the previous block is used in encrypting the current block. The BC is secured by public key cryptography, with each peer generating its own public-private key pairs.

3. *Distributed Database:* A BC is digitally distributed across a number of computers. Each party on a BC has access to the entire database and no single party controls the data or the information. Since BC is decentralized, there is no need for central authorizes such as banks.

4. *Transparency with Pseudonymity:* Each node or participant on a blockchain has a unique 30-plus-character alphanumeric address that identifies it. Users can choose to remain anonymous or provide proof of their identity to others.

5. *Irreversibility of Records:* Once a transaction is entered in the database and the accounts are updated, the records cannot be altered. Records on the database is permanent, chronologically ordered, and available to all others on the network.

There are two types of blockhains: public and private. Public blockchains are cryptocurrencies such as Bitcoin, enabling peer-to-peer transactions. Private blockchains use Blockchain-based platforms such as Ethereum or Blockchain-as-a-service (BaaS) platforms running on private cloud infrastructure. A private BC is an intranet, while a public BC is the Internet. Companies will be disrupted the most by public blockchains.

BCs may be permissioned or permissionless. In a permissioned BC, each participant has a unique identity. Permissionless BCs are appealing because they allow anyone to join, participate or leave the protocol execution without seeking permission from a centralized or distributed authority. However, permissionless BCs, such as Ethereum or Bitcoin, face transaction volume constraints.[6]

There is an impressive, growing list of companies that have started to use to agriculture to safeguard food safety. For example, Walmart, Kroger, Alibaba, IBM, and other companies are implementing blockchain food traceability projects, and using blockchain technology to track the entire process of food production. Coca-Cola has employed it to identify cases of forced labor in the sugarcane supply chain.[7] Some of the applications of blockchain are illustrated in Figure 1.[8]
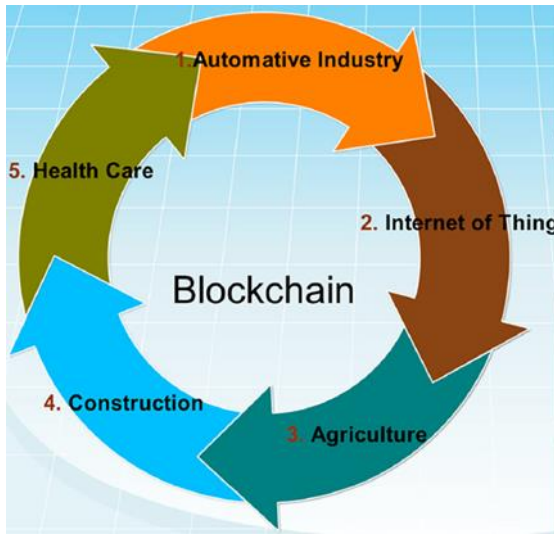
Figure 1: Different applications of blockchain.[8]

Blockain in agriculture

Blockchain technology improves the following areas within the agricultural sector: crop insurance, traceability, smart farming, food supply chain, controlling weather crisis, and transactions of agricultural products.[9, 10]

- *Traceability:* This is the predominate area in agriculture where blockchain is being used. The blockchain tracking system is different from the barcode and RFID systems. Blockchain technology enables consumers to verify the journey of their product, tracing it from farm to table. It enables the traceability of information in the food supply chain and thus helps improve food safety. It also provides data on when a product was harvested in a matter of seconds. Since the information recorded on the blockchain is unalterable, it can provide reliable information and is forgery-proof.

- *Crop Insurance:* Weather condition can threaten agricultural production, putting food security at risk. Agricultural insurance schemes are traditionally recognized as a tool to manage weather related risks. Smart contracts help farmers insure their crops and claim damages with insurance companies. Unpredictable weather anomalies make it difficult to correctly estimate the losses they cause and this leaves room for fraud. Smart contracts insure a farmer's crops and claim damages. Using tailored smart blockchain contracts, the damage claim can be triggered via changes to weather conditions that meet certain criteria.

- *Food Supply Chain:* Supply chain refers to the production and distribution processes of goods and services from suppliers to customers. It is always expedient to provide information on the origins of food products to ensure

customer loyalty and confidence. With traditional supply chains, food re-tailers do not have an effective way of ensuring that all products were grown under specified conditions. The aim of using blockchain technology in the food supply chain is to fulfil the desire of a traceable and transparent system. Blockchain technology allows goods and individuals to be tracked throughout the supply chain based on real time. That is why retail giants such as Walmart resort to blockchain for tracing food products' places of origin. The time it takes to track the origin of food is drastically cut down to just 2 seconds. The blockchain technology in the food supply chain is still in the early stages of development. Figure 2 shows the simplified version of the agri-food supply chain.[11]

- *Transactions:* Blockchain technology allows individuals and businesses to make instant network transactions without any intermediary. Application of cryptocurrency in the transaction of agricultural products will reduce transaction costs more substantially. Each user has a copy of the ledger and access to transaction information. The information of the products is rec-orded and controlled in these transaction records. Blockchain also allows agricultural producers to set prices more efficiently and effectively. This allows managing their output to match the demand for their products.

- *Smart Agriculture:* Smart agriculture refers to the application of the new technologies (such as Internet of things (IoT), cloud computing, global positioning system, artificial intelligence, and big data) into traditional agriculture with the goal of reducing human effort. It implies the wise use of natural resources and the reduction of environmental impact. Someone has claimed that: [12]

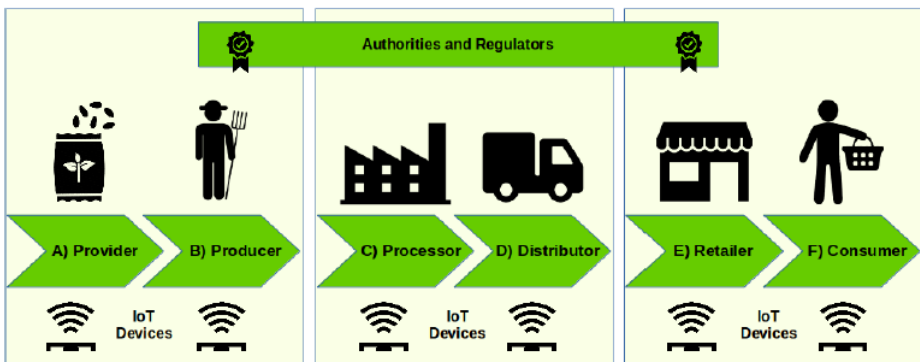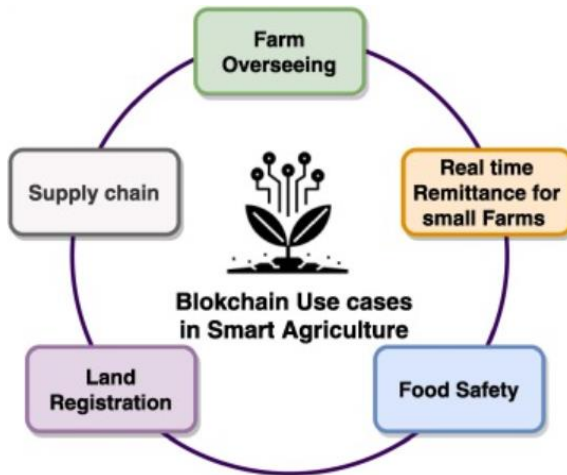<div align="center">Blockchain + IoT = smart agriculture</div>

Figure 2: Simplified version of the agri-food supply chain.[11]

A key issue of establishing smart agriculture is developing a comprehensive security system that facilitates the use and management of data. Traditional way of managing data is a centralized fashion and is prone to inaccurate data, data distortion and misuse as well as cyber-attack. The blockchain technology serves to store data and information that various actors and stakeholders generate throughout the entire value-added process.

Figure 3 illustrated the uses of blockchain in smart agriculture.[13]

Figure 3: The uses of blockchain in smart agriculture.[13]

- *Controlling Weather Crisis:* Farmers usually experience unpredictable weather conditions while growing crops. Being able to predict and monitor weather conditions is therefore essential to crop survival. Consumers do not know when the crops suffered horrible weather conditions and what led to the increased costs. Blockchain has the ability to offer traceability and transparency and provide a clear understanding of the price differences in the food distribution market. Placing agricultural weather stations within the farms can help generate crucial information such as temperature, rainfall, wind speed and direction, and atmospheric pressure. The parameters are measured, recorded, and saved in the blockchain enabling farmers to access them transparently.

Other applications of blockchain technology in agriculture include smart contracts, digital documents, crop and food production, management of agricultural finance, information systems, fraud prevention, automation of work, and decentralization of information.

Benefits

The blockchain technology is reshaping agriculture industry's way of doing business by boosting transaction speeds, helping farmers control and analyze

crops, etc. It is revolutionizing agriculture sector by enhancing the decision-making capabilities of organizations. Blockchain has the ability for agricultural producers to set prices more efficiently. Blockchain agriculture has the potential to increase efficiency, transparency, and trust throughout agricultural supply chains. The use of data distributed in the blockchain network enables transparency of decisions along the supply chain. The stakeholders involved have access to reliable information, allowing better planning and better market control. Other benefits include: [14, 15]

- *Transparency and Trust:* The blockchain can track the provenance of food and help build trustworthy food supply chains. Consumers will be liberated from fakes and regain confidence in ecommerce. This will create trust, transparency, and confidence between producers and consumers.

- *Information Security:* Blockchain technology provides private key encryption which is a powerful tool that provides the authentication requirements.

- *Supply Chain Management:* Blockchain technology can enable supply chain management to operate more efficiently than traditional monitoring mechanisms. Every link in the supply chain represents a "block" of information, with the advantage of visibility, aggregation, validation, automation, and resiliency.

- *Payment Methods:* The blockchain provides a digital payment solution with zero rates. Application of cryptocurrency in the transaction of agricultural products will significantly reduce transaction costs.

- *Reduce the Cost of Farmers.* Many agricultural products are produced by households. Their low transaction volume excludes these participants from the market. Blockchain technology can greatly reduce transaction costs and incorporate them into the market again.

- *Improved Quality Control and Food Safety:* Crop failure, for example, is a prevalent challenge faced by farmers worldwide. It usually happens because of unfavorable climatic conditions, such as poorly distributed rainfall and erratic weather. Blockchain can help us to ensure optimal quality control conditions.

- *Increased Traceability in the Supply Chain;* Today, more and more consumers want to know where their food comes from. Using blockchain technology will let consumers know exactly where their food originated, who planted it, and how fresh it is. Increasing the traceability of the supply chain will have a considerable impact on reducing food fraud and enabling consumers to know what they are paying for.

- *Increased Efficiency for Farmers:* Blockchain technology allows farmers to store their data in one place to easily and be accessed by those who need it. This simplifies the entire process, saves valuable time and energy, and increases efficiency of the farmer.

- *Fairer Payment for Farmers:* Weather conditions, inelastic demand and supply, and the conditions of the global market can impact most farmers' incomes. In the current system, it often takes weeks for farmers to get paid for their goods and payment options such as wire transfers are usually costly. With a blockchain-linked mobile store of data about transaction trends, farmers will be able to negotiate fairer prices. Blockchain-based smart contracts work by triggering payments automatically as soon as a specific, previously-specified condition has been fulfilled. This way farmers can receive payment for their goods as soon as they are delivered.

Challenges

In spite of the enormous benefits of blockchain, key challenges and limitations remain for applying the blockchain technology in agriculture. Current uncertainties are preventing individual parties from developing a convincing business case. Other challenges include:

- *Complex Supply Chain:* The complexity of the modern food supply chain has created distance between the consumer and producer. Supply chain management in agriculture is more complex than other supply chains since agricultural production involves factors like weather, pests, and diseases that are hard to predict and control. Blockchain does not seamlessly integrate with existing legacy systems. The application of blockchain technology requires wide participation and collaboration of involving parties in the agriculture sector.
- *Consumer trust:* Trust is crucial when we desire to improve our economic interactions and impacts. Blockchain technology has changed our notion of trust. An inherent feature of the blockchain technology is its redefining element of "trust." Fear of counterfeiting is a strong reason shoppers may bypass ecommerce platforms.
- *Security:* The issue of security is a challenge since the faster. The blocktime, the more centralization of processing is needed.
- *Awareness:* There is a lack of awareness about the blockchain, and training platforms are non-existent.
- *Legal issues:* There are some legal hurdles to clear before blockchain can really fulfill its potential. Currently, there is no established governance system regulating blockchain transactions.

Global blockchain in agriculture

From boardrooms to kitchens around the world, there is unprecedented demand for a smarter, safer food supply. With increasing globalization and intense market pressure, food supply chains have become more and more dynamic than ever before. According to the United Nations Food and Agriculture Organization, 2.5 billion people in developing nations derived their livelihood from agriculture in 2011. To achieve the vision of global blockchain-enabled food safety, the blockchains of Alibaba, Provenance, Walmart, and others should

cooperate with each other. Blockchain can be utilized by governments for developing world farmers in the global futures market. We consider how some nations apply blockchain in agriculture.

- *United States:* The American organization FarmShare focuses on using the blockchain to tokenize shares, incentivize volunteers, optimize resource sharing and minimize food waste. IBM Food Trust is working with industry leaders to make blockchain innovation uniquely valuable and efficient across various segments of the food industry. Walmart and Kroger were the first companies to embrace blockchain and include the technology into their supply chains.

- *India:* As of March 1 2011, the population of India was 1,210,193,422 (623.7 million males and 586.4 million females). The need to feed such number of people make agriculture the most important sector in India. Agriculture also is the largest source of livelihood in India. Indian agriculture is plagued by many problems with the lack of resources playing the major role. Transparency between the producer and consumer by means of food safety and security is lacking. Blockchain technology in agriculture will be a gamer changer as it can provide tamper-proof, accurate data about the farms, inventory, credit scores, and food tracking. Its main objective is to improve the quality of life of persons living in the society.[16]

- *Europe:* EU governments and the European Commission recognized blockchain-inspired technologies as "key emerging trends" and as having huge potential for the administrations, businesses, and the society in general. Several instruments at EU level will become available to develop blockchain technologies for the agri-food sector. For example. there are more than 133 technological solutions for traceability operating within the Italian market.[17]

- *Indonesia:* Agriculture is one of the largest sectors in Indonesia and creates jobs for at least 38.7 million workers. However, many challenges still remain hampering growth. One of the key issues is the limited data availability in the agriculture sector. Blockchain is a technology that can help to support this database. With blockchain, everyone can access near-time data in the agriculture sector.

- *China:* China is leading in the area of research and applications in agriculture with maximum number of publications followed by USA, Italy, India, and Spain. The Chinese ecommerce giant Alibaba's collaborated with food suppliers in Australia and New Zealand on blockchain pilot for food traceability.[18] The Chinese agri-food supply chain management introduced both formal contractual mechanism and informal trust mechanism for governance. However, the cooperation among participants in the Chinese agri-food supply chain is still unstable and the competitiveness of the agri-food supply chain is still weak.[19]

Conclusions

Blockchain has some unique features such as immutability and transparency, which disallow any fraudulent modifications to the data. The blockchain technology is under development to support agricultural finance by many financial institutions and commercial banks. Blockchain is a disruptive technology that changes businesses and supply chains. It can provide an innovative solution for product traceability in agriculture and food supply chains. The application of blockchain technology in agriculture is still in its infancy. Blockchain is poised to be the disruptive force that propels the agricultural industry into the Twenty-first century.

Although blockchain is a hugely promising technology and has started to revolutionize many industries, it still has a long way to go. It is still new and experimental, and faces a number of significant barriers to adoption in agriculture due to some shortcomings and socio-economic challenges. More information about blockchain in agriculture can be found in the books in [20, 21, 22, 23] and the following related journals: *Frontiers in Blockchain* and *Journal of the Science of Food and Agriculture*.

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