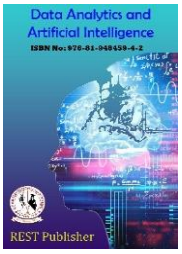
Data Analytics and Artificial Intelligence
Vol: 3(7), 2023
REST Publisher; ISBN: 978-81-948459-4-2
Website: http://restpublisher.com/book-series/daai/



Revolutionizing Agriculture: Exploring the Impact of Blockchain Technology through Case Studies of Innovative

[*]R. Jeyarani, G. Sivaraman
New Horizon College,Kasturi nagar, Bengaluru, Karnataka, India.
M. G. R college, Hosur, Tamilnadu, India.
*Corresponding Author Email: jeyaranimaharajan@gmail.com

Abstract: *Agriculture is one of the areas where blockchain technology could bring a revolution by solving the existing problem of Agri-product fraud, its traceability, price manipulation, and lack of customer trust in the product. This paper aims to demonstrate the potential application of blockchain technology in the agriculture industry and how it could address the existing issues by surveying the existing paper and following case studies of the blockchain start-up companies. Blockchain technology shows a promising approach to fostering a safer, better, more sustainable, and dependable agri-foods system in the future. While the application of blockchain in agriculture is in the initial phase and faces various issues like cost of implementation, privacy, security scalability, performance and infancy, it can bring a revolution in the agriculture industry.*
Keywords: *Blockchain Technology, Trust, Transparency, Security, Traceability.*

1. INTRODUCTION

Agribusiness refers to any business associated with farming and farming-related commercial activities[1]. It is highly multi-stakeholder and distributed, involving many different actors, such as farmers, shipping companies, wholesalers and retailers, distributors, and groceries[2]. In existing agribusiness all the information either resides on paper or private servers and databases of the trusted third parties. Such structure results in an increase of cost to access the data, subject to fraud, corruption, or error that lead to financial losses as well as chances of product counterfeit. The existing agriculture structure lacks (1) the traceability of the product,(2) the security of product information,(3) the trust among the partners in the supply chain, and (4) the trust and confidence of customers in the product's quality[3]. Agriculture is known to be the least digitised industry that missed out to take advantages of the internet, due to lack of connectivity. To address the problems of tracing, food safety, and building trust among the stakeholders in the supply chain some initiatives have been taken in recent years with the use of Information and Communication Technology(ICT). The use of ICT increases the effectiveness and efficiency of data acquisition, storage, analysis, and use in agriculture, enabling all stakeholders to easily get updated information and thus make more effective decisions in their daily farming activities[4]. The main aim was to track and monitor the entire life cycle of food production, including growth, processing, transportation, storage, and selling, which involves a large range of untrusted business parties. But the parties operating the ICT are not fair enough in data collection and its use where they are motivated in using the data in the favour of their interest[5]. Blockchain in general is a distributed database technology that maintains the constantly increasing list of data records that are verified by all the participating nodes in the network [7],[8],[9]. Data records are stored in the blocks and each block is linked together forming the chain. Data within the block are immutable and all the participating nodes within a blockchain network have access to the entire distributed database which eliminates the single node taking control of the data records. Instead of information routed through a central node, each participating nodes store a copy of the data records and forwards to all the remaining nodes within a network enhancing trust and transparency[9]. The working mechanism of the blockchain technology and can be explained as [8],[10],[3]: In the first step the transaction is requested and the block is created. In the next step, the newly created block is broadcasted to all the nodes in the network. All the nodes in the network reach a consensus about the requested transaction and get verified in the next step. Once the transaction gets verified, the block is added to the existing blocks with a new block

of data in the final step. Its application in agribusiness is gradually increasing in recent years that is motivated by the Agri-product fraud that leads to adverse effects on the health of consumers. The main usage of blockchain technology in Agribusinesses focused on product traceability that involves capturing, storing, and transmitting product information in all stages of the Agri-supply chain. Such information enables (1) building trust and transparency among different actors in agri-business, (2) check product's safety and quality, and (3) building customer's confidence and trust. Some of the promising benefits of blockchain adoption in agribusiness can be outlined as:[4],[2]. *Increase Trust:* Blockchain due to its distributed nature and cryptography, the necessity of any central authority for information storage and security is eliminated hence restoring trust between producer and consumers. *Improve Traceability*: The decentralized ledger that records each stage product's information enables to connect inputs from suppliers, producers, buyers, regulators who are relatively apart from each other, help to enhance the traceability of the Agri-products. *Improve product safety and quality*: Product information is recorded at every stage of the supply chain thus allowing all parties to ensure good hygenic conditions, early identification of any contamination, risks, and frauds in products. *The benefit to small farmers:* Small farmers can get a fair market price as they can track the status of the product and changing market price using blockchain technology without depending on the intermediates/middlemen.

TABLE 1. Features of Blockchain Technology

Reference	Features	Explanation
[10]	Decentralization	There is no single point of control and failure where information is stored and shared throughout the network.
[10]	Immutability	Data once stored cannot be deleted or altered
[10]	Peer Verification	Verification of each transaction via consensus among the peers.
[7]	Cryptography	Provides security of transaction and data
[7][8]	Transparency	Data is accessible among all the peers in the network providing transparency
[9][10]	Anonymity	Every participant communicate by generated virtual identity code that cover the real identity of the participant.

2. LITERATURE REVIEW

Blockchain in Food Traceability [5] proposes a blockchain technology and IoT-based food traceability system based which is trusted and self-organized. The authors described the architecture of the proposed system that involves the traditional ERP legacy system and a new IoT system involving all parties in agri- business. The system is a virtual blockchain network consisting of two types of nodes where one is equipped with all functionalities of blockchain node and the other is the thin node which is just a simplified payment verification (SPV) node that only verifies the payment and stores transactional data. IoT technologies eliminate human intervention by replacing manual recording and verification as possible. All actors including customers would be able to access the data stored in the system and verify them using their smart mobile phones thus increasing trust among the actors. Further authors plan to implement smart contracts that would help law executors for problem identification and timely processing. [7] presents an overview of how blockchain technology adoption has enabled the trace of agri- food products. The author also presents a brief explanation about blockchain's architecture, smart contracts, consensus methodology, and types of blockchains. The authors discussed different existing blockchain-based frameworks in combination with IoT and smart contracts whose main aim is food safety and food security. Blockchain provides an immutable distributed ledger with an encryption mechanism to share every product's information at every stage of the supply chain with each stakeholder. blockchain-based systems for tracking and tracing agri-food products. Some of them which are IBM Food Trust to trace the provenance of the Chinese pork products and mangoes, Provenance for tracing fish products, AgriOpenData for tracing whole agri-food, AgriDigital for improving the whole grain supply chain by making it easy, simple and secure to connect farmer and consumer. The authors also present some of the challenges for blockchain implementation despite the technology gaining more and more ground in the supply chain. [8] discuss the application of blockchain in the safety and quality of agri-food in four aspects: *data transparency, data traceability, food safety, and quality*

monitoring, and agriculture finance. The article also presents the case study of the Walmart pork traceability system to demonstrate the use of blockchain technology in traceability. Traditional supply chain management and interaction are unidirectional where the upstream party can only interact with the downstream party. Such systems are unreliable and inefficient where various supply chain actors do not have enough information about the product that could trace its origin in case of any food contamination or any issues. Blockchain with its immutable and decentralized nature can connect all aspects of the supply chain and records enough information at every stage from food production to food at the consumer table. All the information about the product could be accessed by all the participating parties hence increasing transparency and building trust among each other. The digital data is recorded at every stage of the supply chain, e.g. farmer, food processor, packer, distributors, and retailer. Data recorded in blockchain are immutable and accessible to all parties, which enables to trace of the products. Real-time food tracing systems based on blockchain technology provides an information platform that allows all supply chain members to access all information connected with a specific food item, enabling food supply chains openness, transparency, neutrality, dependability, and security. Blockchain records every information about the product at every stage like the number of pesticides, artificial colorants, food chemicals, appearance, temperature, humidity, light gas that are essential to monitoring the product safety and quality. For agricultural financial services, blockchain technology can provide quick and real-time payments, lowering the transactional costs that increase cash flow and working capital. Blockchain enables low-cost, quick, and secure payments that eliminate the burden on farmers. The payments can be done within few minutes with very few transaction fees without the involvement of any middle agents like remittances or banks. Hence blockchain enables efficient agricultural financial transactions with an enhanced supply chain.

3. BLOCKCHAIN APPROACHES IN AGRICULTURE

The use of blockchain technology in agriculture is growing which leads to the development of a blockchain-based system where agribusiness activities can be executed. We selected six start-up companies that have implemented the blockchain-based solution in agriculture as case studies to examine the application and benefits of adopting blockchain technology. There were no precise criteria for selecting the cases other than that they have implemented the blockchain-based solution in agriculture. We gathered additional data from internet sources like industry journals, blogs, news stores, and company websites as well as scholarly and practitioner literature on innovation management and food business. We focused on the information about how blockchain technology was implemented to address various issues in agriculture. Table 2 highlights some of the insights of the cases we selected. Table 3 summarize our findings. Case 1- Agri Digital -: The Agri Digital platform is an integrated commodities management solution for the global grains industry that uses the Ethereum blockchain to promote transparency and efficiency, restoring farmer trust in the ecosystem. Agri Digital is the world's first settlement of an agricultural commodity on a blockchain which enables real-time payment removing the counterparty risk for the seller. Agri Digital aims to make the global supply chain simple, easy, and secure. Agri digital software is flexible, simple, and easy to use. Agri Digital is a web-based platform that may be accessed from a computer, tablet, or smartphone. The platform is composed of five core modules[10]: *Transactions:* This module allows the farmer and stakeholder to buy and sell the goods easily by handling all components of buying, selling, and logistics. *Storage:* All the information including payments, orders, deliveries, inventory, and confidential information are stored digitally in this module. *Connections:* Farmer and costumer can expand their connection using this module. *Finance:* This allows execution of all financial transactions and transfer of virtual currency(token) between farmers and consumers. *Remit:* The remittances issued to the farmer are automatically transferred. Blockchain technology was used in removing counterparty risk for sellers through real-time payment, automating and democratizing access to supply chain financing for buyers, and guaranteeing that all consumers have access to the provenance of their commodities to make informed purchase decisions. The platform records all the critical data about farming, production, transportation, and delivery of products on the cloud enabling it to address food fraud and security the in global supply chain. Farmer gets notification of each move like when their crops are delivered on the site to a buyer, or payment of invoice has been complete. The Agri Digital created the digital title to a physical commodity by developing the token. These tokens representing physical commodity remains in the blockchain which means immutable information could be accessed by everyone, hence creating *'digital trust'* among all the participants in the supply chain.[10]. Being the world's first company to executed live-ever settlement of the physical product on the blockchain between grower and a buyer, Agri digital now has 300 active users and is operating in 30 countries. From the pilot project that were successfully executed, the main contribution of Agri digital in agribusiness can be summarized as:

- provides an opportunity to connect the local farmers to the global supply chain.
- tracking of real-time data (location, status of the assets at any given time) of a grain sale between grower and the buyer for transparent supply chain.
- execution of the real-time payment settlement via smart contract, that that help to eliminates the

counterparty or credit risk to the grower where it ideally would take two to five weeks for payment in Australian grains industry.

- offering customers with comprehensive trade flow management, access to funding and traceability of the item's origins
- provides AgriDigital users with full scale trade flow management, access to finance and traceability of the item's origin.

***Case 2- TE-FOOD*:** TE-FOOD is a public permissioned blockchain-based farm-to-table food traceability system that enables all supply chain participants and the customer to trace the food's information. The FoodChain (TE-FOOD's blockchain) is a public permissioned blockchain that allows supply chain actors and consumers to maintain master nodes to decentralize traceability information. Customers of TE-FOOD have the flexibility to gain in-depth insights into the food industry's supply chain. TFD is TE-ERC20 FOOD's token, which is mostly used on the Ethereum platform. Its mission is to offer transparency in the food supply chain by monitoring the items through the whole supply chain (farm, processors or slaughterhouse, distributor, retailer) and providing tools to customers, supply chain firms, and government agencies to learn about food history and quality. The TE-FOOD aims to increase consumer trust and brand exposure, obtain greater supply chain knowledge to improve operational efficiency, comply with export rules, protect their brands from counterfeiting, and execute faster product recalls . TE-Food system comprises of : *Identification Tools:* It includes 1D/2D barcodes/RFID ear tags, security seals. and label stickers. *Traceability tools:* It consists of a B2B traceability administration mobile app, web app, central system, external interfaces, and reporting tools. *Retail and consumer tools* include B2C fresh produce history insight mobile app, and web app, retail side food history digital signage tools. *National livestock management solutions*: It consists of livestock administration and enforcement systems. *Farm management tools:* These tools are based upon the category-specific (Vaccination, feeding, fertilizers, plant protection products, etc.). *Food safety tools:* These tools include a Fraud management system, Food condition sensor equipment, Meat quality visual analysis system.

To identify the tracked physical objects (products, locations, etc), the system implements different identifications materials: *plastic seals with QR codes, plastic identification tags with RFID,* and *paper-based label sticker with QR codes).* For traceability, it provides different client applications: *mobile app* used by B2B and customer to scan identification materials and request/enter data, *Web App* for the customer who does not use the mobile app to access the product history, *IoT API* for food companies that enable to combine information received from the sensors and *Open Interface* for supply chain companies who use software already to handle product's information .TE-FOOD offers two implementation models, private or institutional. In Private implementation, a system is used to trace their activities while in Institutional implementation, authorities or public government, the system is used to trace a group of companies(geographically or industry category related). TE-FOOD comes with the full package of tools and applications needed for the whole supply chain to implement food traceability by end-to-end operational visibility and process control.

TE-FOOD being focused on food trackability, provides unique solutions in agricultural industry:

- It is only the trackability solution that offers different services B2B(Business-to- Business), B2C(Business-to-Consumer) and B2A (Business-to-Authorities), benefiting businesses, consumers and authorities.
- It builds consumer trust as they are able to track the origin of the food product including all processing the product underwent.
- Due to proper trackability facility and IoT sensors, the food product that are contaminated can be quarantined at early stage before it reaches to retailer, reducing various foodborne illness.
- Regulatory bodies have real-time perspective of the food market that help to improve food safety regulatory monitoring and enforcement.

***Case 3- Etherisc*:** It is an open-source development platform that focuses on building decentralized crop insurance applications. Etherisc builds decentralized, blockchain-centric applications for different sectors of the insurance industry. Etherisc's blockchain crop insurance solution has been successfully tested in a Srilanka in collaboration with Aon and Oxfam to lower risk and cover the risk effectively, in 2019. In November 2020, Etherisc has announced to team up with Chainlink to deliver crop insurance in Kenya whose objective is to trigger insurance payouts automatically in case of extreme weather events. Ethernet's crop insurance solution is developed on Etherisc's Etherium based "Generic Insurance Framework" that uses local metrological parameters as an input to the smart contract. The decentralized oracle network of Chainlink provides a secure and reliable end-to-end connection to different external weather data sources and broadcast the data to the smart contracts for all the parties so they can verify the information independently.

In the case of extreme weather events, insurance policies are triggered automatically by the input data which

result in fair, timely, and transparent payouts where an insurer is not able to tamper or alter. Users may choose their agricultural product and field location in the Crop Insurance Application, then apply for insurance by paying Ether to a DAPP (aka "smart contract"). They receive an automatic, immediate payout in the event of a drought or flood. Algorithms in the smart contract automatically check GPS and weather station data depending on the location of the farmer's fields, which allows Etherisc to assess risk and contract conditions cost-effectively at the outset and handle claims over time. The insurer saves time and money by eliminating a labour-intensive procedure. The risk of human error is also reduced through automation. This can cut down on fraud while also making claim payouts more efficient.

Being crop insurance company based on blockchain technology, it has positive impact in agriculture industry:

- Instant payment are triggered based on the weather data without making farmer to claim, removing a time consuming and labour intensive task that not only make farmer easy but also adds transparency.
- Automatic trigger of insurance policy with weather data as input mitigates the risk of human errors and risk of human frauds at the time of pay-out.

***Case 4- AgriLedger*:** AgriLedger is a social entrepreneurship initiative for agricultural farmers that uses distributed ledger technology and mobile applications. It is a mobile application build on R3's Corda (blockchain platform) that provides a comprehensive set of integrated services to all the participants in the supply chain building trust among each other. In 2019, AgriLedger launched a blockchain ecosystem for Haitian farmers to increase supply chain transparency and promote more equitable product pricing for suppliers and retailers. The mission of AgriLedger is to empower small farmers by making easy processes to access the global market via the mobile platform and financial services via API links with local banks and financial institutions. The application mainly focuses on traceability and payment that will allow the producer to retain ownership until the final sale. Blockchain technology is used to record and verify, payment and money transfer, digital identity, and smart contracting. Here is how Agriledger simplifies the access of farmers to the global market. For instance: A farmer from Haiti drops off 500 mangoes at a collection point, where they are counted. Those 500 mangoes are registered (digitally) in the farmer's name in blockchain(say block1). Those mangoes from the collection point are delivered to Port-au-Prince(Haiti's capital) and are delivered to the US (say block 2). After a week, they arrived in the US(say block 3) and those mangoes were sold to the supermarket on the next day (say block 4). Here customers can learn how those mangoes were delivered by scanning the QR code sticker. On the other hand, farmers get notified by sending SMS when the mangoes are sold at the destination market. With AgriLedger, every farmer, supplier, Agri-product, receives a unique ID or QR code sticker that must be processed at each stage of the way. The person holding the scanner may only add data to the distributed ledger, and their ID is recorded each time they do so. This way digital information is recorded at every stage of the supply chain that can be trusted by everyone in the chain. With trustworthy data stored in an immutable distributed ledger has enabled the rural farmer(in Haiti) in making educated decisions, demonstrate financial stability, and go to the bank and obtain a loan.

AgriLedger besides its huge economic impact on farmer's living, it struggle with some issues such as:

- Security of the farmer's private key, which in case someone got access to it they could perform unauthorized transactions.
- Application inappropriate for the farmers who are illiterate, especially in developing country.
- Infrastructure issues like electricity for mobile charging, internet accessibility and network cover in remote areas.

Case 6-AgUnity: AgUnity is a blockchain-based smartphone app that helps small farmers in planning, trading, and tracking their daily transactions. It is built on a Multichain blockchain platform that enables to connects farmers with buyers, enhances transparency, and provides them the money they need to succeed in a global market. AgUnity aims to improve enhance farmer's economic condition and overall negotiating power with the use of blockchain and smartphone solutions, reducing food waste and farmer inefficiencies. So far AgUnity has initiated two pilots projects in Kenya and Bougainville.

TABLE 2. List of blockchain-based companies and insights

S. N	Case	Insight 1	Insight 2	Insight 3
1	AgriDigital	The world's first blockchain-based agricultural commodities settlement	Remove counterparty risk for sellers through real-time payment	Creates the 'digital title' to a physical commodity by developing the token.
2	TE-Food	Provide greater food traceability	Increase consumer trust and brand exposure and obtain greater supply chain knowledge	Offer two implementation model: private and institutional
3	Esterisc	Offer blockchain-based cr op insurance solution to lower risk and cover the risk effectively	Insurance policies are triggered automatically, enabling the farmer to receive automatic, immediate payout in case of extreme events	Enables to cut down on fraud while also making claim payouts more efficient
4	AgriLedger	Focus on traceability of products and payment that will allow the producer to retain ownership until the final sale	Digital wallet facilitates farmer in applying and receiving direct deposit from the financial institution.	Asset Digitization through tokenization facilitates liquidity and peer-to-peer trading.

TABLE 3. Technical Implementation of the cases

Cases	Platform	Application	Objective
AgriDigital	Ethereum	Web Application	Financial, Supervision and Management
TE-FOOD	Hyperledger	Mobile Application	Traceability
Esterisc	Ethereum	Web Application	Crop Insurance
AgriLedger	R3 Corda	Mobile Application	Transparency, Financial
AgUnity	Multichain	Mobile Application	Small Farmer Support

4. DISCUSSION

Literature review and case study about the initiative implementing the blockchain technology reveal that it would solve the existing problem seen in the traditional and typical agriculture supply chain. Many pilot projects have been launched all around the globe that aims to address the current problems seen in the agriculture industry. Blockchain as a distributed ledger where information once recorded is impossible to alter would be a perfect solution for a transparent agricultural supply chain enabling information tracing, food safety, and quality. Study shows that much of the agricultural sectors are using or planning to use permissioned blockchain(R3 Corda, Multichain, Hyperledger) as it is flexible enough to allow companies to modify the ledger's rules at their choice, allowing for the cheaper transaction, better privacy and reducing the risk of traditional consensus-based assaults.

5. CONCLUSION

Blockchain technology would be a transformative technology soon in the agriculture industry that could address several issues like inefficiency in the traditional supply chain, food safety, security and quality issues, high transactional cost, market manipulation by middlemen, distrust of the consumer on the product. Some of the efforts can be seen through several initiatives around the globe. With some of the successful initial adoption of the technology in agriculture, its demand is increasing. But for blockchain to come to full fruition, issues (cost, scalability, performance, data privacy, technical maturity, security) need to be resolved. Limitation of our survey is that some of the case studies explored are very recent and ongoing experimentations. So all the analysis are based upon the early outcome and evidence available currently. Further research on large use cases and mature block-chain projects would give real picture of advantages of blockchain technology in agriculture. Also data for case analysis are collected from publicly available data like reports, news, blogs and website due to lack of first hand investigation of blockchain start- ups. Further research based on interviews and surveys of targeted actors would have benefited this study more. I would like to thank everyone, who supported me to complete this article.

REFERENCES

[1]. V. S. Yadav and A.R. Singh, "A systematic literature review of blockchain technology in agriculture.", In Proceedings of the International Conference on Industrial Engineering and Operations Management , pp. 973-981,July 2019.
[2]. Kamilaris , A. Fonts and F.X. Prenafeta-Boldύ, "The rise of blockchain technology in agriculture and food supply chains". Trends in Food Science & Technology, 91, pp. 640-652, 2019
[3]. G.A. Motta, B. Tekinerdogan and I.N. Athanasiadis, "Blockchain applications in the agri-food domain: the first wave.", Frontiers in Blockchain, vol. 3, p. 6, Feb 2020.
[4]. H. Xiong, T. Dalhaus , P. Wang and J. Huang, "Blockchain technology for agriculture: applications and rationale.", Frontiers in Blockchain, vol.3, p. 7, 2020.
[5]. J. Lin, Z. Shen, A. Zhang and Y. Chai, "Blockchain and IoT-based food traceability for smart agriculture.", In Proceedings of the 3rd International Conference on Crowd Science and Engineering , pp. 1-6, July 2018.
[6]. Y.P. Lin, J.R. Petway, J. Anthony, H. Mukhtar, S.W. Liao, C.F. Chou and Y.F. Ho, "Blockchain: The evolutionary next step for ICT e-agriculture.", Environments, vol. 4, p.50, 2017.
[7]. K. Demestichas, N. Peppes, T. Alexakis and E. Adamopoulou, "Blockchain in agriculture traceability systems: a review.", Applied Sciences, vol. 10, p.4113, 2020.
[8]. J. Xu, S. Guo, D. Xie and Y. Yan, "Blockchain: A new safeguard for agri-foods". Artificial Intelligence in Agriculture, vol. 4, pp.153-161, 2020.
[9]. D. Gunasekera and E. Valenzuela, "Adoption of blockchain technology in the Australian grains trade: An assessment of potential economic effects". Economic Papers: A journal of applied economics and policy, vol. 39, pp. 152-161, 2020.
[10]. M. Torky and A.E. Hassanein, "Integrating blockchain and the internet of things in precision agriculture: Analysis, opportunities, and challenges.", Computers and Electronics in Agriculture, p. 105476, 2020.