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Research Survey on Role of Blockchain Technology in Agriculture

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Abstract

Blockchain is a decentralized ledger technology where all the data and information can be stored and shared. They allow accessibility for every network users rather than just a single server and admin. The information in the database can then be accessed and validated by several parties, increasing security and lowering the risk of corruption. Traceability is made possible by blockchain's ability to store and manage data. This feature is used to help develop and execute solutions for index-based crop insurance and intelligent farming. It is an important advance in the fields of modern agriculture. Food safety in agriculture is ensured by blockchain applications in crop certification, information systems, agro-trade, financing, and traceability of origin, among other areas. It offers a trustworthy source of information regarding contracts, inventories, and farm conditions in agriculture, an industry where obtaining such data is frequently exceedingly expensive. Because food traceability can be tracked via blockchain technology, reliable food supply chains and consumer-producer trust can be established. It makes it easier to employ data-driven technology to improve farming because it is a reliable method of storing data. Additionally, when combined with smart contracts, it enables prompt payments between parties that may be brought about by modifications to data that appear in the blockchain. The applications of blockchain technology from a theoretical and practical standpoint in smart farming, food supply chains, agricultural insurance, and agricultural product transactions. With numerous current initiatives in various food items and food-related difficulties, blockchain is a promising technology towards a transparent food supply chain. However, there are still many obstacles and hurdles that prevent its greater appeal among farmers and systems. Technical issues, education, legislation, and regulatory frameworks are all involved in these challenges.

Key words: Agriculture, Blockchain, Supply chain, Farming, Traceability

1. Introduction

Blockchain technology greatly improves database tracking and information flow maintenance through the use of Information and Communication Technology (ICT). Blockchain technology offers increased security and lowers the possibility of corruption in the agriculture industry by enabling multiple parties to access and authenticate new database modifications, in contrast to traditional setups. Although there are numerous active initiatives pertaining to different food items and food-related issues, blockchain technology has great promise for a transparent food supply chain. However, there are still numerous obstacles and hurdles that impede its wider adoption among farmers and systems. Technical issues, policy, education, and regulatory frameworks are some of these problems.

Numerous facets of business, government, and society at large are already being revolutionised by such changes, but it's important to prepare for potential new difficulties and issues that may arise. Smart contracts, decentralised apps, blockchain, and distributed ledger technology (DLTs) are all combined in many of these new applications to essentially eliminate censorship or manipulation by other organisations.

1.1 Blockchain

The data is stored on a decentralised node network called blockchain. It is a very good technology for safeguarding private information inside the system. Important data can be exchanged while maintaining security and confidentiality thanks to this technology. It is the ideal solution for securely keeping all the relevant documents in one place. Blockchain also expedites the process of searching a single patient database for candidates who meet particular trial requirements. The Blockchain is a decentralised peer-to-peer (P2P) network of individual computers known as nodes that maintains, saves, and logs transaction or historical data.

1.2 Uses of Blockchain Technologies in Agriculture

Blockchain technology can track a variety of plant-related data, including crop growth and seed quality. It can even provide a record of a plant's journey after it leaves the farm. By using this data, supply chain openness may be increased and worries about unethical and criminal activity can be allayed. They can also facilitate the process of tracing contamination or other problems back to their original source in the event of a recall. In the event of a recall, they can also assist in tracing contamination or other problems back to their original source. Security of food supply and sustainability are the main goals of these technologies. Food security and sustainability are these technologies' main objectives.

1.3 How to apply Block chain Technology in Agriculture?

There are various blockchain uses in the agricultural sector, and more are being developed based on recent technological advancements. To analyse the key uses of blockchain, it is feasible to divide it into four broad categories:

1. Intelligent Farming
2. Food Supply Chain
3. Insurance for Agriculture
4. Agricultural Product Transactions
5. Smart Agriculture

Smart farming, sometimes referred to as smart agriculture, is the process of utilising a variety of recent technological advancements to improve the farming operation's dependability and efficiency. It combines a variety of data collection and analysis tools, including unmanned aerial vehicles, machine learning technologies, various sensors, information and communication technology (ICT), and the internet of things (IoT). Although the relationship between smart technology and farming is still developing, it can greatly simplify operations with the correct security system in place.

The centralization of all the processes in the outdated approach to managing smart technology frequently results in various errors and distortions in the data collection process. Additionally, it exposes the system as a whole to the cyber-attack. Every stakeholder involved can provide crucial data at any point, from the sale of different agricultural goods to the seed stage. The way blockchain maintains data transparency and complete immutability of all statistics is what really grabs my attention. The biggest advantage of blockchain in smart agriculture is definitely its decentralisation feature. This avoids data loss and distortion and allows for the smooth distribution of data to multiple stakeholders. Every transaction on a blockchain is time-stamped, which increases transparency and boosts overall process reliability.

The application of blockchain technology in the food supply chain is still in its infancy. However, there are still a lot of unfinished and immature stages in the blockchain technology implementation process. In addition, for blockchain technology to be fully utilised, a large number of stakeholders in the food supply chain must collaborate and participate. Food quality data can be tracked across the whole supply chain according to blockchain technology's decentralisation, security, and transparency features. This lowers the expenses associated with managing the food supply chain and prevents fraud in food transactions. As a result, everyone stands to gain—producers, customers, and government regulatory agencies included.

From ICT to Blockchain

Bias in data gathering and utilisation is still present in information and communication technology. People who use ICT are always driven to use information in a way that serves their personal interests. For instance, the organisation a stakeholder represents has a significant impact on their preference in a multi-criteria decision (Collier et al., 2014), and NGOs may focus excessively on certain topics because of their interest (Ngo Monitor, 2015). Making data modification challenging or even impossible by giving a huge number of people access to data management capabilities is a good method to prevent this kind of bias.

A blockchain is a ledger where participants alternately log details about the creation, sale, and use of goods and services. All involved parties administer the ledger cooperatively, usually via a peer-to-peer network. Before a new record is added to the blockchain, it must first be validated by the network. Consensus decision-making protocol should be followed for any changes made to the recorded data, which means that most persons involved must agree.

Furthermore, any changes made to one record will also affect all of its succeeding records. As a result, changing data that is really recorded on a blockchain is quite difficult. According to Iansiti and Lakhani (2017), blockchain is "an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way." Blockchain is a revolutionary ICT that could Completely change the agriculture data used. Although the issue of consensus has been thoroughly examined by scholars in the past, its application to the blockchain space has provided fresh inspiration and incentives, inspiring creative solutions for blockchain system architecture.

For the purpose of confirming transactions and enabling their addition to the blockchain, the most popular method—known as "Proof of Work" (PoW)—requires computer nodes, referred to as miners in this context, to complete challenging computational jobs (Bentov, Gabizon, & Mizrahi, 2016). The block is added to the chain by the first miner to solve the problem, and they are rewarded with freshly created coins plus a tiny transaction fee once the rest of the

miners validate it. It was believed that the agricultural industry employed blockchain technology to ensure food security, stop food fraud, and confirm the legitimacy and provenance of agricultural inputs and products.

Findings:

Through blockchain technology, parties involved in the agricultural value chain can identify illegal agents and defective or subpar procedures, improving traceability and transparency. This guarantees that, from farm to market, optimal conditions are sought. When food safety fails, it is critical to be able to track the origin of food products. Food producers will be able to take prompt measures to avoid illness and ultimately save lives if the source of contamination is identified early. By reducing financial fallout, such a prompt response will also help reduce food waste and save money.

Implications/Recommendations:

Blockchain technology holds great promise for the agricultural industry. It can be used to guarantee food safety by tracing the origin of agricultural products and any potential sources of contamination, as well as verifying the authenticity of farming inputs. It can also be utilised in the process of distributing subsidies to farmers, ensuring that they receive the benefits of subsidy programmes. Lastly, blockchain technology will provide farmers with better prices and payment options, as well as resolving issues with land title sales and purchase registration.

Contribution:

The agriculture industry is new to blockchain technology, and there are still many obstacles to overcome.A well-established system for controlling blockchain transactions does not yet exist.

Still, there are bright prospects for using blockchain in agriculture.

Different role of blockchain in Agriculture

1.Smart Farming Model

The value and promise of blockchain in agriculture have led to several smart farming models, which help to bring the advantages of this technology together with IoT sensors. One such architecture has been developed for greenhouses, utilizing a private blockchain that can be managed centrally by the farmer.

Another general-purpose approach has been presented, which also uses IoT technologies and blockchain. The basic premise of this framework is to aid in the development of trust among blockchain participants. Numerous stakeholders may use smartphones to access data created at every stage of the farming process, from seeding to product sales.

2. Smart Farming Technology

Organizations such as Filament have begun to develop smart agricultural technology. One example is a business that sells products with smart farming technology that connects multiple networks to actual items. The business created a coin-sized piece of technology to assist users in safe transactions against a blockchain.

3. Food Supply Chain

The food supply chain has grown longer and more intensive than ever because of globalization trends. However, there are several challenges in the food supply chain, including food safety, quality, traceability, trust, and supply chain inefficiencies. These factors burden the economy and society and endanger customers' health.

Many of these issues can be resolved with the help of blockchain technology since it makes it easier for producers and consumers to build confidence. Providing detailed product information on the blockchain will greatly improve process transparency. This has significant effects on both businesses and farmers. By increasing the value of their products, firms can become more competitive in the market. Furthermore, if these practices persisted, it would be highly unlikely that suppliers of phoney or subpar items could maintain a profitable business for very long.

When it comes to giving consumers reliable and authentic information about the origins of their food, blockchain technology can play a vital role. It can be used to a variety of consumer concerns around food safety, quality, and environmental friendliness. As consumers have a greater understanding of the food production process, they are better equipped to communicate with food producers.
From the standpoint of a regulator, blockchain benefits are clear in that it gives necessary institutions access to trustworthy information that helps them enforce effective regulations.

Because of the various ways that blockchain may be applied to the administration and supply chain of food, a lot of businesses have already started implementing it in agricultural operations. Blockchain-based traceability initiatives are being used by Wal-Mart, JD.com, and Alibaba to closely monitor their entire food manufacturing, processing, and sales process.

4. Agricultural Insurance

The whole agricultural process is now more uncertain due to recent climate change. Extreme weather can affect the quality of animals and agriculture. Agricultural insurance programmes are frequently used by farmers to lesson the unpredictable nature of farming.

Farmers have a choice of insurance programmes with different methods for determining payouts and evaluating losses. Agricultural insurance commonly comes in the form of indemnity-based insurance, which compensates farmers based on the findings of an expert who inspects the farm for damage. Nevertheless, farmers and insurance firms suffer from indemnity-based insurance's various limitations regarding damage assessment and the insurer's lack of knowledge.

The utilisation of blockchain technology makes index-based insurance a more advantageous option than indemnity-based insurance. By basing the compensation process on a measurable metric rather than the actual loss, it improves the accuracy of the insurance procedure overall.

5. Transactions of Agricultural Products

The use of blockchain technology can significantly speed up the acquisition and sale of agricultural products on ecommerce sites. It does so in two ways:

Data Security: Blockchain provides a secure authentication system with private key encryption, increasing the authenticity of all data acquired throughout planting and harvesting.

Supply Chain Management: In terms of supply chain management, blockchain can increase overall efficiency by lowering the costs associated with signalling. Furthermore, it contributes to safety by providing digital payment solutions that eliminate transaction costs.

The use of cryptocurrencies in this technique will also reduce transaction costs. These changes all contribute to a more trusting relationship between customers and sellers. This has numerous implications for farmers, who stand to make significantly more money on their products and get a larger audience for their goods via the internet.

Blockchain can help to enhance index-based insurance in the following ways:

1.It is possible to switch the payment foundation to an automated and timely criterion, such meteorological data. This option may cause the payout to terminate based on the smart contract's expressly defined parameters.
2. Secondly, all data sources, including meteorological and plant development data, would be provided by the system via an oracle. This significantly enhances index determination and the payment procedure.

Among the many companies utilising smart index insurance contracts is Etherisc, a Swiss company that helps farmers receive decentralised crop insurance through blockchain technology. These contracts improve overall dependability and are in use all around the world. Farmers in places like India, for instance, are presently using them to get crop insurance payments based on meteorological data. The total dependability of this process is raised by these payments.

Additionally, the lack of a middleman or other third party in a blockchain-based system reduces transaction costs. The system is more efficient because these transactions are also irreversible and do not require the intervention of any governmental or commercial agency as a mediator. The system and programming provide complete proof, so the participants don't need to trust each other. The following three definitions of blockchain are widely used:

- In terms of technology, it is a black-end database with the ability to be publicly viewed and that keeps track of a distributed ledger.
- From a business perspective ,it is an exchange network that allows peers to move assets, value and transactions amongst one another without the use of middlemen.
- Legally speaking ,it validates transaction history ,replacing previously trusted entities.

Everyone in the village has the original note concerning the transaction, thus none of the two persons involved in it can claim to have received false information or dispute it. Additionally, in order to fabricate the information, the fraudster would need to alter every copy's note in the village, which is not feasible under normal circumstances. In a similar vein, imagine that these transactions take place on computers, and that each hamlet has a unique computer that houses the record. Additionally, anonymous approvers, often known as miners, authenticate, and verify these transactions using cryptography. This is how things function in a real blockchain system, where all data and records are kept in blocks and shared among all network users. Any further transactions is added in the new block and linked with previous blocks. Since it is cryptographically secured and thus can't be mutable by any fraudulent.

Classification of Blockchain Research in Agriculture

The literature was classified under four head namely traceability, architecture and security, information systems and other applications of blockchain in agriculture field.

- Traceability:

In the food supply chain, traceability is seen to be an effective method for monitoring food safety. Researchers and supply chain managers have experimented with a number of traceability-enhancing techniques, including RFID tagging and digitization. However, none of them have shown to be 100% reliable. Still, blockchain might be a true lifesaver in certain situations. This has been corroborated by a number of reputable organisations, including IBM, Walmart, Tsinghua University, and others, using real-world case studies. In a case study, IBM and Walmart used blockchain to follow a mango's trip from farm to fork in 2.3 seconds, compared to more than a week in an older Walmart system. On Bigchain, the system was constructed.

All stakeholders in the agro-food supply chain will benefit from DB's openness, transparency, security, neutrality, and dependability. A permissioned blockchain system called "ProductChain" was presented by Malik et al. (2018) to track the source of food. The simulation's outcome demonstrated that questions were responded to in milliseconds and that trade flows among food chain stakeholders were kept private. A small number of academics also used blockchain and IoT for traceability. In these systems, data was recoded using IoT devices, and the provenance of the data was traced using blockchain technology. Throughout the supply chain, the authors were able to effectively integrate IoT devices for the production and consumption of digital data. They tested their blockchain-based system implementation using use cases. Ethereum and Hyperledger Sawtooth were the two platforms used for the implementation. As blockchain based system doesn't have control on sensor through which data are fed to blockchain system, if such sensors are manipulated it will difficult to catch such fraudulent.

Information System:

Blockchain was used by a small number of authors to deliver content in the right format at the right time and place. Blockchain technology was deemed valuable by the writers for tracking, auditing, and monitoring the food supply chain.

They discovered that blockchain was helpful in improving supply chain efficiency and that it benefited producers, consumers, and government supervision departments. In order to confirm the concept's usefulness, the author additionally asked stakeholders to rate their Quality of Experience using a questionnaire. The Luxembourg Slovenian Business Club, founded by Petec and Zajec (2018), set the foundation for blockchain-based information sharing, facilitating the development of communication tools for decentralised food and nutrition parties. Their platform is called "CONFIDENCE." Blockchain-based information systems were highlighted by Andreevich et al. (2018) as a means of maximising its implementation.

Architecture and Security:

Researchers have improved the design and security elements of the current blockchain-based system to reduce risk. In order to solve the issue of automating agricultural procedures, the double chain system was devised. In order to address a few problems with the Chinese public platform for agro-products, Leng et al. (2018) suggested a double-chain architecture based on blockchain that consists of a storage module and dual chain structure. Blockchain technology was presented by Patil et al. (2018) as a greenhouse farming security solution based on the Internet of Things. In order to facilitate secure communication for greenhouse farming, a suitable framework was created by integrating blockchain technology with Internet of Things devices.

Other applications:

Although tractability appears to be a frequently discussed aspect of blockchain technology in agriculture, there are other noteworthy uses as well. Kim and Laskowski (2017) investigated blockchain's use in agriculture. The authors categorised agricultural applications into three categories: agrofinance, sustainable agriculture methods, and food safety. According to Papa et al. (2017), who looked at the potential applications of blockchain in the agribusiness sector, such a system might increase transparency by efficiently monitoring agricultural commerce. Yadav et al. (2018) created an Ethereum Platform blockchain-based application for online food court ordering payments. A blockchain-based framework was developed by Kumar and Iyengar (2017) to address a significant issue in the rice supply chain in the Indian setting. In order to illustrate the value of the suggested blockchain-based architecture for food safety, the authors have provided an example scenario. A blockchain-based solution was put out by Yadav and Singh (2019) to solve farmer concerns in the Indian setting. A decentralised system built on blockchain technology was created by Pinna and Ibba (2019) to address the main problems with contract workers.

How Can Blockchain for Supply Chain Help Farmers?

These days, consumers want to know the actual source of their food. Agribusinesses are looking for supply chain management software to enhance food safety, food quality, and the traceability of the entire farming supply chain. This is due to the growing desire for healthier eating and the rising use of technology across all disciplines. Better food production and supply chain management in agriculture are made possible for agricultural enterprises by precision farming, precision agriculture solutions, farmland mapping, Internet of Things sensors, vertical farming systems,

location intelligence, crop management software, and transportation technology. More food is consumed, which raises other issues. For example, fake goods might compromise food supply chains at different points in time. Inefficiency and a lack of openness hurt farmers and consumers. Lastly, distributed ledger technology (DLT) and block chain farming have the potential to increase the trust, transparency, and efficiency of the agricultural supply chain. Blockchain for the agriculture supply chain has the potential to empower all market participants through the creation of trustworthy relationships.

Agriculture business may be transformed by blockchain for supply chain by:

- Simplifying all phases of the agricultural supply chain
- Following a product from farm to retail shelf
- Increasing food safety and removing counterfeit goods
- Lowering financial risks and encouraging inclusive trade
- Making agricultural finance services available to farmers and companies
- Using Data Science in agriculture to provide smarter market data for improved decision-making; legally demonstrating certifications to necessary authorities

How Blockchain Benefits Agriculture and Food Industry?

The benefits of blockchain in the agriculture supply chain are:

- Transparency
- Analytics
- Security
- Streamlined operations
- Customer engagement

Blockchain use cases in Smart Agriculture

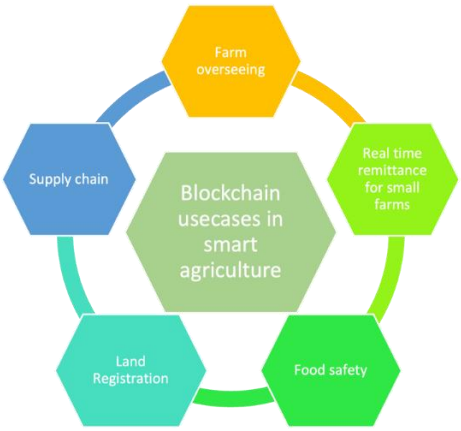

Fig 1: Block chain use cases in Smart Agriculture

State of Blockchain Technology in Agriculture Worldwide

With the use of distributed ledgers and smart contracts, blockchain technology in agriculture has the potential to eradicate counterfeit products in the production and supply chains of agri-food, improving living standards for consumers worldwide and fostering greater trust among industry players. Through thorough investigation and practical testing of blockchain applications in the agri-food sector, businesses may start to identify the best use cases of blockchain technology to fortify the agricultural supply chain. Here are some ways that blockchain benefits farmers:

1. Food Safety

Blockchain technology in agriculture has the same potential to be beneficial as Internet of Things technology. The urgent need for supply chain control and product traceability can be effectively and reliably addressed by the blockchain. A blockchain stores product information at every stage of the agricultural supply chain, reducing duplication of effort, enhancing quality control, and monitoring storage conditions. Smart IoT sensors are presently used by agricultural businesses to monitor crops; distributed ledger technology will enhance sensing technologies by gathering and verifying all data.

2. Agricultural Insurance

Distributed ledger-based smart insurance contracts that self-execute will enhance insurance policies for individual farmers, farms, and supply chain partners. Insurance claim evaluation will no longer require human intervention thanks to smart contracts, which will streamline, accelerate, and improve transparency of the process. The contracts will also lessen the possibility of fictitious claims and provider corruption because once insurance policies are agreed upon, actors cannot alter them.

3. Agricultural Finances

Blockchain technology may provide transparency to agricultural credit records, financial agreements, and transactions for smallholders who want to invest in farming. While maintaining fair market pricing, smaller farmers will be able to pay for machinery and raw materials in instalments or after delivery thanks to shared access and irrevocable agreements.

4. Environmental Sustainability

Agriculture is more affected than other industries by climate change and erratic weather. Agribusinesses are accountable not only for the future of our world but also for following the rules of many environmental initiatives like green bonds and climate change. Businesses are facing mounting pressure to track, confirm, and disclose sustainability standards in order to convince investors of their environmentally friendly farming practices and maintain business operations.

Advantages of Blockchain Technology in Agriculture

With this configuration, peer-to-peer architecture and encryption are trusted instead of a centralised authority. Rebuilding trust between producers and consumers is greatly impacted by this change, which eventually lowers transaction costs in the agri-food industry. The agricultural industry finds blockchain technology to be a dependable means of enabling clear and straightforward transactions. The intricacy of the agri-food system makes it easier to manage the challenge of tracking down

goods in the extensive supply chain. As a result, technology provides answers to issues about food safety and quality that affect consumers, the government,
and other stakeholders. Blockchain technology facilitates the capture of verified data and encourages transparency among all parties. Blockchain can record every stage of a product's value chain, from conception to death. The trustworthy data on the agricultural process is extremely helpful for building data-driven facilities and insurance solutions to make farming smarter and less susceptible.

Potential Blockchain Technology Benefits for Agriculture

With the use of blockchain technology, peer-to-peer transactions can occur in a transparent manner without the involvement of a middleman in the agriculture industry or a bank, as is the case with cryptocurrencies. Trust is now placed in encryption and peer-to-peer architecture rather than in an authority since the technology does away with the necessity for a central authority. In the agri-food sector, it can lower transaction costs by fostering a relationship of trust between farmers and consumers.

A trustworthy method for tracking transactions between anonymous individuals is provided by blockchain technology. Thus, fraud and defects can be promptly identified. Furthermore, the integration of smart contracts enables real-time reporting of issues (Haveson et al., 2017; Sylvester, 2019). This aids in addressing the difficulty in tracing products in the extensive supply chain that arises from the intricate agri-food system. So, food safety and quality concerns—which the public, government, etc., are deeply worried about—are addressed by technology.

Transparency between all stakeholders is facilitated by blockchain technology, which also makes it easier to gather trustworthy data. From a product's conception to its demise, blockchain can document every stage of its value chain. Reliable farming process data are extremely helpful for building data-driven infrastructure and insurance plans that make farming more intelligent and less risky.

Applications

The four classes of applications in agricultural and food sectors: agricultural insurance, smart farming, food supply chain, and transactions of agricultural products.

Agricultural Insurance

Historically, agricultural insurance programmes have been an established means of mitigating weather-related hazards. In this case, farmers receive an insurance payout for any losses they sustain on their property and pay an insurance premium prior to the start of the cropping cycle. Farmers are able to control their financial exposure to weather extremes, or the financial losses brought on by weather extremes, as a result of the insurer bearing all insured risk. Additionally, the insurer

can further hedge the systemic portion of the risk with a reinsurance business in the event that weather hazards affect all of the insured farmers systemically (Miranda and Glauber, 1997).

There are differences between agricultural insurance policies in terms of how losses are evaluated and, in turn, how payouts are initiated. Indemnity-based insurances are those that provide farmers with compensation based on an expert's damage assessment that was completed on the farm. Although indemnity-based insurances can accurately pay for losses, they are vulnerable to issues brought on by asymmetric knowledge issues. More precisely, farmer and insurer have unequal access to information regarding the riskiness of agricultural production and production practices. It is believed that farmers possess greater knowledge of the factors that encourage moral hazard and adverse selection.

Compared to farmers with lower risk, those with a higher ex ante risk exposure are more inclined to get insurance, according to the adverse selection theory. Moral hazard suggests that when farmers receive insurance, they switch to riskier production techniques. Insufficient information on the two cases by the insurer causes the insurance scheme to fail on the market. Because of this, indemnity-based insurances are vulnerable to expensive damage assessment and must take precautions—like deductibles—to prevent issues brought on by asymmetric information. Furthermore, even though they cause financial harm, things that cannot be measured, like grazed meadows, cannot be insured.

Index-based insurances: The concept of index-based insurances originated as a substitute for or addition to traditional products, spurred by the shortcomings of indemnity-based insurances (Turvey, 2001). In this case, a quantifiable indicator—like rainfall at a nearby weather station—instead than the actual loss itself triggers the reward (Barnett and Mahul, 2007; Barnett et al., 2008). In addition, farming techniques have no bearing on the insurance payout; if this weather station has long enough historical weather records, both the farmer and the insurer have the same knowledge about the insured value. As a result, moral hazard and adverse selection became irrelevant, and the technical process needed to initiate a payout was greatly streamlined.

Furthermore, it is possible to have complete insurance coverage with no deductibles, and payments can be sent automatically and on time right after a negative weather occurrence is recorded. On the other hand, basis risk refers to the possibility of differences between payout and on-farm loss (Woodard and Garcia, 2008). There are three possible sources of basis risk. Any variations between recorded and on-farm weather, such as those resulting from spatial distance, are indicated by spatial basis risk (Ritter et al., 2014; Dalhaus and Finger, 2016). Temporal basis risk, such as full year rainfall versus growth season rainfall, suggests that an imprecise time window was used for index determination (Conradt et al., 2015; Dalhaus et al., 2018). According to Leblois et al. (2014), design basis risk encapsulates the remaining factors, such as biassed technical implementation or missing meteorological variables.

In summary, basis risk reduction is of primary interest, and index insurances are becoming an increasingly significant risk management instrument for farmers. There are two ways in which blockchain might enhance index insurance. First, depending on meteorological data that initiates the payout as specified by a smart contract, payments can be issued automatically and on time. Second, a smart oracle can automatically integrate data from various sources, including plant growth information and data acquired by farm machinery, and weather information, reducing basis risk and increasing the efficiency of the index determination and payout process (Gatteschi et al., 2018). Other crypto-economic applications have previously demonstrated the value of smart contracts that incorporate external data through the use of smart oracles (Harz et al., 2019).

Initial iterations of smart index insurance contract prototypes are currently being developed or introduced. For example, Etherisc1, a Swiss business, offers blockchain-based decentralised crop insurance with rewards based on meteorological data in native DIP currency (DIP – Decentralised Insurance Protocol tokens). Additionally, WorldCover2, a New York City-based insurance company that offers index insurance contracts to Ghanaian smallholder farmers, mimicked the use of a smart contract based on the Ethereum blockchain. Payments would therefore be issued in Ether, a cryptocurrency. Arbol3 is an additional astute crop insurance provider. Farmers can offer contracts at Arbol that comprise a payout, a premium payment, and a weather event that initiates the payout. An investor acting as a counterparty may then accept that suggested contract. Ether is used for both the initial and final payments (Jha et al., 2018).

Beyond the aforementioned benefits of decentralised insurances based on smart contracts that automatically pay out, it is still necessary to demonstrate in practice whether bitcoin rewards may be used to reimburse farmers. Furthermore, it's possible that farmers—particularly those in underdeveloped nations—lack access to the technology needed to take part in a decentralised blockchain-based insurance scheme. First, third-party companies "[...] can offer payment gateways and integrations which remove the necessity to own cryptocurrency from the end customer," suggests Etherisc (Mussenbrock, 2017).

Smart Agriculture

The fundamental data and knowledge about the natural resources that sustain all types of farming form the foundation of agri-food systems. Depending on their requirements and capabilities, many actors and stakeholders produce and handle data and information. The use of ICT, the internet of things (IoT), and several contemporary technologies for data collecting and analysis, including as unmanned aerial vehicles (UAV), sensors, and machine learning, are characteristics of smart agriculture. Creating a thorough security system that makes data administration and use easier is a crucial part of implementing smart agriculture. Conventional methods handle data in a centralised manner and are vulnerable to cyberattacks, erroneous data, and data distortion and misuse. For instance, centralised government organisations with competing interests typically oversee data from environmental monitoring programmes. They have the ability to sway data-related decisions.

More ways Blockchain can aid farmers:

- Better product quality and fewer food-related illnesses;
- Equitable pricing for all parties involved in the value chain;
- Sustainable business practices and waste reduction;
- Small farmer financing and insurance
- Facilitation of financial transactions in developing economies;
- Traceability throughout the value chain;

- Reduction of emissions and support for environmentally beneficial activities;
- Increased consumer awareness and satisfaction;
- More informed decisions made by consumers regarding purchases;
- Lower transaction fees and less dependence on intermediaries;
- Transparent transactions and the eradication of fraud;
- Legal protection of privacy while granting access to data

Future Research Directions:

While the field of study on blockchain adoption is still in its infancy, the number of publications has increased, indicating a growing interest in this field. In light of this, this paper examines pertinent research on blockchain's use in the agriculture industry. According to several reviews, blockchain technology has a bright future in the agricultural sector. Scalability, interoperability, proof of verification mechanisms, and other significant implementation-related concerns with blockchain technology do exist, though. A few other challenges include creating a better architecture to strengthen security features in blockchain-based systems against 51% attacks, which occur when someone gains the majority in a network and abuses it, DNS attacks, which deprive peers of information, DDoS attacks, which flood new blocks with transactions, consensus delay, which stops peers from reaching an agreement, double spending attacks, which result in the creation of two transactions from a single unspent transaction, and selfish mining, which occurs when miners try to maximise their rewards by keeping blocks private. Increasing the speed of blockchain-based transactions is another significant concern.

Seven transactions are currently recorded every second (Croman et al., 2016), and concerns over power consumption and storage for blockchain-based systems are growing. A few examples of preliminary blockchain technology study could be as follows:

• How might blockchain technology be utilised to integrate precision agricultural activities?

• Since farmers and other agro-supply chain stakeholders are typically low-tech, it will be important to consider how easily the blockchain-based solution can be made available to them.

• It is necessary to investigate if a blockchain-based system complies with regulatory requirements.

• One potential area of focus is offering a workable solution for integrating blockchain technology with the current food supply chain network.

Food Supply Cain

Food supply chains are longer and more complicated than they have ever been due to rising market rivalry and globalisation. Food supply networks frequently face issues with food traceability, food safety and quality, food trust, and supply chain inefficiencies, all of which increase the dangers to the general public's health, the economy, and society as a whole. By

openly sharing specific product information on the blockchain, producers believe that using blockchain technology can help them develop trusting relationships with customers and enhance the reputation of their products. Businesses can boost their competitiveness by better achieving the value of their products. This would make it more difficult for vendors who engage in fraud and provide subpar goods to remain in the market and would compel all vendors to raise the calibre of their offerings across the board in the food and agriculture industries. From a perspective of the consumer, the blockchain provides accurate and trustworthy information regarding the production and distribution of food. In terms of food safety, quality, and environmental friendliness, it helps allay customer concerns (Ge et al., 2017). Because customers can more easily and thoroughly comprehend the food production process, the adoption of blockchain opens up the possibility of consumer-producer interaction. By lowering barriers to the interchange of goods, it helps consumers build stronger relationships and, consequently, greater trust and confidence in the safety of food. From the standpoint of the regulatory bodies, blockchain provides them with precise and dependable information so they may implement laws that are well-informed and effective (Zhou et al., 2016; Chen, 2018).

Blockchain technology can document a product's history from the manufacturer to the retail outlet. It offers an unchangeable, safe method of preserving information gathered at the beginning of the supply chain, such as the DNA of livestock animals and pesticide residues on grains and vegetables. Anybody connected to the product's supply chain can examine and validate such information. Although it can be done on samples, gathering this kind of data for every product can be highly expensive. Transparency in this kind of data can be used to identify, for example, the containment of undeclared meat, as was the case in the European horse meat crisis of 2013 (Kamath, 2018; Montecchi et al., 2019).

Numerous strategies to enhance the traceability of agricultural products have been put forth, many of which are made possible by blockchain technology. Tian (2016) suggests utilising Radio Frequency Identification (RFID), a non-contact automatic identification communication technology, to create a traceability system for the agricultural food supply chain. It is able to track products along the whole supply chain using reliable information. Utilising blockchain ensures that the production, process, store, and distribute records within the system are authentic and trustworthy. A blockchain-based traceability system that is easily integrated with Internet of Things (IoT) devices—which supply digital data on production and consumption—was proposed by Caro et al. (2018). Both the Ethereum and Hyperledger Sawtooth blockchain technologies are used to achieve the traceability.

E-Commerce of Agricultural Products

The trade and e-commerce of agricultural products need to find solutions for a few major issues. First, Tiago et al. (2017) have shown that customers who have a high level of general trust are more likely to make purchases online; yet, consumers find it difficult to verify and trust fundamental information on agricultural products. However, the two biggest issues facing e-commerce businesses, particularly in developing nations, are cash on delivery and logistics services (Reddy and Divekar,

2014). Additionally, time-consuming small orders with a variety of items are handled by e-commerce shops (Boysen et al., 2019), which drives up operating costs for e-commerce businesses.

Numerous parts of these issues may have appropriate answers thanks to blockchain technology:

(1) Security of information. According to Xu et al. (2016), blockchain technology offers private key encryption, a potent tool that satisfies the requirements for authentication. As a result, it may securely and irreversibly link the data pertaining to every facet of agricultural product planting and harvesting.

(2) Management of the supply chain. By reducing the cost of signalling for each entity, blockchain technology ma With the benefits of visibility, aggregation, validation, automation, and resilience, each link in the supply chain—the producer, the place of origin, the shipping company, the destination, the multimodal transport, the warehouse, and the last mile—represents a "block" of information (Babich and Hilary, 2018).

(3) Modes of payment. Zero-rate digital payment solutions are offered by the blockchain. Moreover, using cryptocurrencies in agricultural commodity transactions will significantly lower transaction costs.

(4) Customer assurance. The distributed accounting system of the blockchain is time-stamped by the decentralised method, making all data on the chain transparent and unchangeable. Customers will be freed from impersonators and develop faith in online shopping (Karame, 2016).y make supply chain management more effective than current monitoring techniques (Chod et al., 2019).

(5) Lower the price for farmers. Households create a lot of agricultural goods. These players are shut out of the market because traditional e-commerce is unable or unable to serve them due to their tiny size and low transaction volume. Transaction expenses can be significantly decreased and reintroduced into the market with the use of blockchain technology.

While it might not be used throughout the entire process, several businesses are already putting this technology to use in practice. Customers can now query all manufacturing information and track the origin of every product at the Old Farmers' Shopping Mall, an online retailer in the Hubei Province of China, thanks to the use of blockchain technology4. Details such as sowing, watering, fertilising, and de-worming have been documented before the commodities are placed on the platform. Basic information on producers, logistics of transit, storage days, and storage temperature are also provided. To access all the information, customers simply need to scan the unique QR code located on the goods. Customers only need to scan the QR code on the goods, which is unique, and all the information will be available to visit. This method can effectively avoid the forgery of bad merchants, and reconstruct consumers trust in agricultural products from e-commerce and its suppliers.

Although the current situation is not ideal, blockchain technology is still being applied in the e-commerce and trade of agricultural products. For instance, there are still issues with how to guarantee the validity of the data uploading procedure into blockchain. Internet of Things could be a future answer. Further investigation and analysis of blockchain's distributed, non-tamperable, and traceable features are required to raise the productivity and efficiency of agricultural commerce and production.

Limitations

Food safety is enhanced by the blockchain technology, which makes information traceability in the food supply chain possible. It offers a safe method for handling and storing data, which makes it easier to create and apply data-driven innovations for intelligent farming and intelligent index-based agricultural insurance. It can also lower transaction costs, which will help farmers access markets and create new sources of income. There are still significant obstacles in the way of using blockchain technology in the food and agriculture industries, despite its great potential benefits.

First, more investigation is needed into the reasons behind the transacting parties' willingness to supply accurate and true data to the blockchain ledger. In the instance of smallholder farming, this may be particularly crucial. The knowledge produced while farming is dispersed and belongs to certain farmers. The advantages of blockchain technology for farmers may vary based on the size of the farm. Smaller farms may, on the one hand, simply join an insurance market based on blockchain technology. However, larger farms may find it more convenient to gather and integrate on-farm data. Future studies should therefore aim to predict which farms stand to gain and which stand to lose from the use of blockchain-based solutions.

Second, the expense of getting data uploaded to a blockchain will prevent blockchain technology from being widely used in this industry. While setting up a distributed ledger may not cost much, gathering the information needed to make the ledger functional—such as farm animal DNA—may. Sampling has the potential to save costs, but it needs a large product population for data collecting. This indicates that larger farms have lower average data gathering costs than smaller farms, which raises the possibility of the revenue gap widening.

Third, there isn't a direct, seamless integration between blockchain and the current traditional systems. The technology must be connected to legacy systems like factory execution systems, enterprise resource planning, and warehousing management in order for it to be properly integrated. It can take a while to build the infrastructure needed to employ blockchain technology. The communication protocol and middleware that can unite current systems will be crucial.

What are the Challenges of Blockchain Technology in Agriculture?

Food safety is improved by blockchain technology, which makes information in the food supply chain traceable. By offering a secure way to store and manage data, it makes it possible to develop and implement data-driven technologies for smart farming and smart index-based crop insurance.
It may also result in decreased transaction costs, which would enhance farmers' access to markets and open up new revenue streams. There are many drawbacks to applying blockchain technology in the food and agriculture sectors, despite its enormous potential. In my opinion, more research is necessary, especially to comprehend the reasons behind transacting

parties' precise information contributions to the blockchain ledger—a critical component, especially when it comes to smallholder farming.

Knowledge developed during farming is owned and shared by individual farmers. Depending on the size of the farm, blockchain technology may or may not benefit farmers. Smaller farms, meanwhile, might easily participate in a blockchain-based insurance market. On the other side, larger farms might find it easier to gather and combine on-farm data. Therefore, it would be worthwhile for future research to try and forecast which farms would benefit and which will suffer from the adoption of blockchain-based solutions.

Second, the cost of obtaining data uploaded to a blockchain will prevent the industry from using blockchain technology. A distributed ledger can be set up for relatively little money, but collecting the data—like DNA from farm animals—that the ledger needs to function could be expensive. Costs can be reduced by sampling, but gathering data from a large population of things is necessary. This suggests that larger farms typically pay less for data collection than do smaller farms, which raises concerns about the income gap widening.

Third, there is no direct interaction between blockchain and the existing legacy systems. For the technology to be successfully adopted, it must be integrated with an existing database and legacy systems like industrial execution systems, enterprise resource planning, and warehouse management. It takes time to build the infrastructure needed to support blockchain technology. It will be essential to have middleware and communication protocols that can link existing systems.

- **Adoption and Implementation**: Farmers, especially in developing regions, may face challenges in adopting blockchain technology due to lack of infrastructure, digital literacy, and initial investment costs.
- **Data Privacy**: Ensuring the privacy and security of sensitive data on blockchain is crucial, particularly in agriculture where proprietary data can be highly valuable.
- **Scalability**: Blockchain networks need to be scalable to handle large volumes of transactions, which can be a challenge in sectors with extensive supply chains like agriculture.
- **Regulatory Environment**: The regulatory framework for blockchain in agriculture is still evolving, and clear guidelines are necessary to ensure compliance and foster innovation.

Conclusion

This study was focused on studying the current developments of blockchain research and uses in agriculture area. For this objective, the study accounted articles from all main databases and publishing partners. It was revealed that China is leading this area of research with largest number of publications followed by USA, Italy, India and Spain. It was also found that the study on blockchain is limited to only few nations and most the publications occurred as proposal in conference rather than journal and book chapters. There were just few papers which genuinely focus on implementation side of the blockchain based system. The material was also evaluated under four areas of research dimensions namely traceability, architecture and security, information systems and other applications in agriculture field. It was observed that blockchain based research in agriculture is mainly focused on traceability and specific research whereas notable research also exist for blockchain architecture and security design and blockchain as information system. However few important issues related to blockchain

implementation exists like scalability, interoperability, application of blockchain for precision agriculture and food supply chain network design etc. which are emerging areas for further studies. We hope this review motivate scholars to take this call to solve some of the socio-economic concerns encompassing blockchain for improving society.

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