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A Comprehensive Review on Emerging Technologies in Agricultural Sector

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***Abstract*- This paper presents a comprehensive literature review on the utilization of Internet of Things (IoT), and Blockchain technologies in the agricultural sector. The rapid growth of these industries has led to their adoption by major tech companies and governments worldwide, particularly in areas such as healthcare, property registration, real estate, securing public data, and agriculture. The integration of Blockchain enhances data security, facilitates secure peer-to-peer data transfers and transactions, ensures the immutability of data on a ledger, and promotes transparency among peers. Smart contracts further contribute to time and cost savings by eliminating the need for third-party authentication in specific transactions. On the other hand, IoT offers a platform for storing and updating environmental records relevant to farmers, encompassing climate change, temperature, soil moisture, wind speed, water management, crop monitoring, and the controlled usage of pesticides and insecticides. These parameters are monitored and recorded by smart sensors, and the collected information is displayed on a unified platform, providing farmers with a comprehensive overview of their agricultural operations.**

Keywords: Internet of Things (IoT), Blockchain, Smart contract, Immutable ledger.

I. INTRODUCTION

Day by day, the world population is increasing, and projections indicate that it will reach 10 billion by 2050 and around 12 billion by the end of the century [1]. With this population growth comes an increased demand for food. However, meeting this demand is challenging due to various factors such as climate change, food quality maintenance, financial constraints, and pesticide usage. To address these challenges, tech companies have been focusing on leveraging technology in the agricultural sector, particularly through the concept of smart agriculture. Smart agriculture involves the integration of technologies to make farming more efficient and sustainable. The combination of the Internet of Things (IoT) and Blockchain has emerged as a promising initiative in this regard. By utilizing these technologies, it becomes possible to sense, collect, store, and communicate data to different components within the agricultural ecosystem. One pressing issue in the agricultural sector is the migration of young people to cities, leaving behind aging farmers who continue to work in their fields well into their 60s, 70s, and 80s. This raises the question of whether now is the right time for IoT and blockchain to collaborate in the field of agriculture. By implementing these technologies, there is potential to attract migrant workers back to agriculture by providing them with opportunities to contribute technologically to the sector. The Internet of Things enables the use of smart sensors, which gather data and provide updates on climate change, soil moisture levels, airspeed, and water management systems. However, many existing IoT solutions rely on heavily centralized cloud infrastructures, which often lack transparency and present security risks such as data lock-in, confidentiality issues, and auditability [2].

The forthcoming section II of the paper will present a literature review that addresses the aforementioned problems. The subsequent sections of this paper are organized as follows: Section III provides an overview of the current state of adopting blockchains for traceability in agri-food supply chains and outlines the system architecture of Agri BlockET. Section IV presents the analysis of preliminary results, and Section V concludes the paper.

II. LITERATURE REVIEW

The reviewed literature, several studies have explored the application of IoT and Blockchain technologies in the agricultural sector. These studies

Table 1: Criteria for Review

No.	*Criteria*
1	Applying blockchain and the Internet of Things in the agriculture sector
2	The study must be an informative collection of original research papers and survey papers.
3	Reviewing the solution in the agriculture sector.
4	Cover ways in shifting to smart agriculture.

highlight various benefits and advancements achieved through the integration of these technologies. In Paper [3], the authors conducted a survey on the implementation of IoT in agriculture in Eastern countries such as China, Malaysia, Taiwan, and Thailand. They found that the leading to precision farming and improved plant growth. Additionally, an IoT system was developed for fruit traceability, providing advantages for sellers and exporters. Researchers in Paper [4] discuss different IoT-based agriculture applications, including monitoring air, water, soil, livestock, and plants, as well as irrigation, pesticides and insecticides control, smart greenhouse systems, and food supply chain tracking. They also address security issues associated with IoT-based smart agriculture and explore the usage and application of blockchain technology for enhanced security. The paper conclude with future research direction, such as protection against selfish mining. In paper [5], the author focus on developing a device for soil moisture and water

management in agriculture. This device ensures the security of irrigation systems by informing farmers and service teams about any malfunctions and taking necessary actions to resolve the issues. It also monitors water levels and the efficiency of fertilizers, identifying specific fertilizers that may be causing reduced efficiency. The device utilizes sensors to measure soil pH value, nutrition levels, and fertilizer excessiveness. Two research papers, [6] and [7], propose software architectural models for smart agriculture. In the first paper, a five-layer architecture for the Community Support Agriculture (CSA) model in Vietnam is introduced. The layers include application, service, distributed ledger, smart contract, and blockchain network. This model facilitates consistent traceability and implements novel smart contracts to optimize the number of transactions recorded on the blockchain. The second paper addresses challenges related to distributor-exporter relationships, uncertain food quality, and high packing costs. Their proposed solution involves the use of smart stickers with unique IDs that enable consumers to track the journey of goods through simple smartphone scans.

These literature reviews demonstrate the diverse applications of IoT and Blockchain in agriculture, ranging from precision farming and fruit traceability to soil moisture management, food supply chain tracking, and smart contract-based solutions. The integration of these technologies holds promise for enhancing agricultural practices and addressing various challenges faced by the industry.

III. METHODS

In this section, we state the method used to conduct this study, which includes the eligibility criteria, information sources and search After conducting a thorough review of existing research papers, it is evident that IoT, blockchain, and AI are highly effective technologies in reducing human efforts in agriculture across various stages, including irrigation, seed distribution, and product sales. These technologies have the potential to address modern-day challenges faced by farmers, such as climate irregularities, population growth, and limited resources. The integration of IoT and blockchain in smart agriculture offers transparency, security, and improved management systems. By utilizing IoT devices such as drones, farmers can remotely monitor and manage their crops, including watering and assessing their health. The collected data can be securely stored on the blockchain, ensuring its integrity and accessibility for future analysis and decision-making. Furthermore, the implementation of AI in agriculture brings additional benefits. AI algorithms can process vast amounts of data collected by IoT

devices, and provide valuable insights for crop health, disease detection, pest control, and yield prediction. This enables farmers to make informed

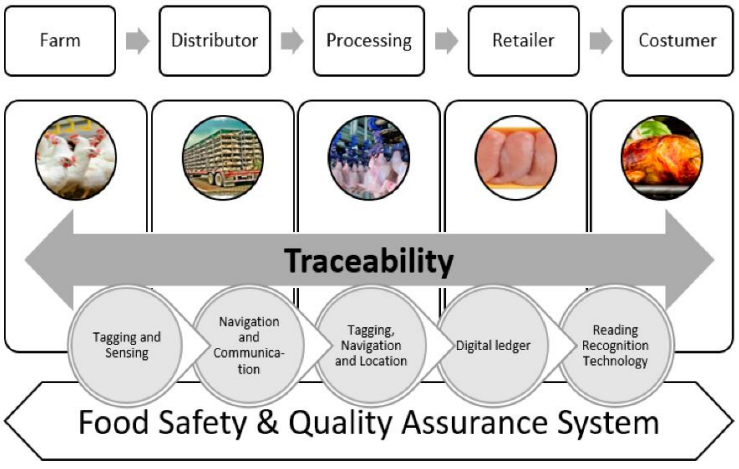


FIGURE 1 STRUCTURE OF FOOD TRACEABILITY SYSTEM

TABLE 2: A SUMMARY TABLE OF REPRESENTATIVE TECHNICAL INNOVATIONS IN AGRICULTURE

Paper Reference	Problems Addressed	Main Features	Contribution
Leng et al.[19]	lowering privacy and redundant storage risks	Double-chain arrangement	Improvement of confidentiality and elimination of duplication
Si et al. [20]	IoTs have a large storage overhead	Partial Blind Signature, Small IoT	Data compression and increased privacy
Hao et al.[21]	Real-time monitoring data is stored in large amounts	IPFS	Storage of real-time IoT data with IPFS
Novo[22]	IoT devices have accessibility and scalability issues	Access control system	Design of an IoT scalable access architecture

decisions and optimize their farming practices. By combining these technologies, farmers can tackle various challenges, including climate irregularities, population growth, and water scarcity. Real-time monitoring and data analysis offered by IoT and AI empower farmers to adapt to changing environmental conditions and make resource efficient decisions. Moreover, the use of blockchain in agricultural transactions enhances transparency and trust between buyers and sellers. It enables secure and traceable supply chains, ensuring the authenticity and quality of agricultural products. Decentralized applications based on blockchain technology provide a single source of truth for all parties involved. The such as the utilization of drone networks for crop watering, health monitoring, and data collection, showcases the potential of these technologies in revolutionizing the agricultural sector. These advancements not only reduce human efforts but also contribute to sustainable farming practices and optimize resource management. However, it is important to acknowledge that challenges remain, including infrastructure limitations, data privacy concerns, and technology adoption barriers. Further research, collaboration, and investment are necessary to overcome these challenges and fully harness the transformative benefits of IoT, and blockchain, and AI in the agriculture sector. In conclusion, the integration of IoT, blockchain, and AI in smart agriculture presents a significant opportunity to alleviate the burden on farmers and address the pressing challenges they face. These technologies offer enhanced efficiency, transparency, and sustainability, paving the way for a more advanced and secure agriculture management system.

Blockchain in agriculture sector

In the agriculture sector, which involves multiple levels of transactions with varying terms and conditions, blockchain technology can simplify processes and enhance transparency. Blockchain operates as an immutable ledger that is difficult to tamper with. It consists of nodes connected in chains, with each node possessing its own private and public key, providing a unique identity. The use of blockchain brings transparency within the agricultural ecosystem. Participants in the system, including authenticators, validators, buyers, and sellers, can access and verify information stored on the blockchain. This transparency helps create trust and accountability among stakeholders. By developing a decentralized application [9] (DApp) using blockchain technology, transparency between customers and sellers can be established. This DApp serves as a platform where comprehensive information about a product and its associated transactions can be easily accessed with a single click. The immutability of blockchain ensures that the recorded information remains unchanged over time, enhancing the reliability of agricultural transactions. It becomes difficult for malicious actors to alter or manipulate data on the blockchain, promoting integrity and trust in the system. One of the significant advantages of blockchain in the agriculture sector is the ability to create transparent supply chains. Customers can verify the origin, quality, and authenticity of agricultural products by accessing the information stored on the blockchain. This helps in reducing fraud, ensuring fair pricing, and promoting consumer confidence. Additionally, the use of smart contracts in blockchain-based systems automates and streamlines agricultural transactions. Smart contracts are self-executing agreements that enforce predefined terms and conditions. By eliminating the need for intermediaries, smart contracts reduce costs, minimize delays, and increase the efficiency of agricultural transactions. Blockchain's decentralized nature ensures that data is distributed across multiple nodes, reducing the risk of a single point of failure and enhancing the security and resilience of the agricultural management system. However, it is important to consider challenges related to scalability, interoperability, and data privacy when implementing blockchain in the agriculture sector. Further research and collaboration are needed to address these challenges and unlock the full potential of blockchain technology in revolutionizing agricultural processes.

- ***Smart contracts:*** Smart contracts are indeed digital contracts that are coded with specific rules, terms, and conditions using programming

languages like Solidity. They enable automated and secure transactions without the need for intermediaries. In the context of the agriculture sector, smart contracts can bring numerous benefits. Farmers can utilize smart contracts for various purposes, such as conducting financial transactions, managing land partitions, and verifying documents. These contracts can be programmed to comply with government regulations, ensuring that all necessary verification processes are carried out without the need for physical visits to government offices. This saves time and provides convenience for farmers, allowing them to focus on their agricultural activities. One of the significant advantages of smart contracts is their ability to track the distribution of agricultural goods from farmers to customers [9]. The terms and conditions of the contract can include details such as quality standards, pricing, and delivery requirements. By leveraging smart contracts, farmers can streamline their business operations, reduce paperwork, and eliminate the need for intermediaries in certain transactions. This can lead to cost savings, increased efficiency, and improved trust between parties involved in agricultural transactions.

Internet of Things in agriculture

Climate monitoring is an essential aspect of agriculture, and the Internet of Things (IoT) has emerged as a valuable technology for this purpose. The IoT enables the connectivity of various electronic devices to the internet, ranging from smartwatches and air conditioners to robotics cars. In the context of agriculture, IoT can also be applied, as demonstrated by several researchers. Studies [8], [12], and [13] highlight how IoT can be integrated into the agriculture sector through the use of drones.

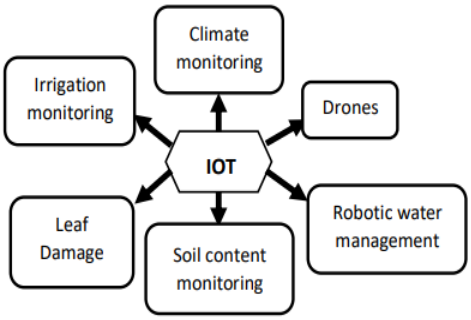


FIGURE 2 ADAPTATION OF IOT IN MULTIPLE AREAS

Drones equipped with sensors can scan entire fields, allowing farmers to observe crop conditions and detect invasive species and weeds. These technologies enable more efficient and accurate monitoring of crop health and can help farmers identify areas that require attention. Furthermore, research studies [14] and [15] showcase the use of unmanned aerial vehicles (UAVs) in seed sowing, crop irrigation, and data collection for assessing crop health. These UAVs leverage blockchain-based decentralized security to ensure the integrity and privacy of the collected data. This combination of IoT, drones, and blockchain provides a comprehensive and secure solution for agricultural operations. By leveraging IoT technologies, farmers can gain real-time insights into the environmental conditions affecting their crops, such as temperature, humidity, and soil moisture. This information enables them to make informed decisions regarding irrigation, pest control, and other farming practices, leading to improved crop yields and resource management. Integration of IoT in agriculture facilitates data-driven decision-making and enables farmers to optimize their operations based on accurate and up-to-date information. It enhances precision agriculture by allowing farmers to target specific areas of concern and take appropriate actions to mitigate potential risks. Overall, the use of IoT in agriculture, particularly in combination with drone technologies and blockchain security, offers significant benefits in terms of monitoring and managing crop conditions. It enables farmers to take proactive measures to ensure optimal crop growth, improve resource efficiency, and ultimately enhance the overall productivity and sustainability of agricultural practices.

In order to conduct a thorough literature review, various digital databases were manually searched to retrieve relevant research information. The main topics used in the search process included:

1. Internet of Things in the agriculture sector
2. Blockchain in the agriculture sector
3. Blockchain security
4. IoT and Blockchain

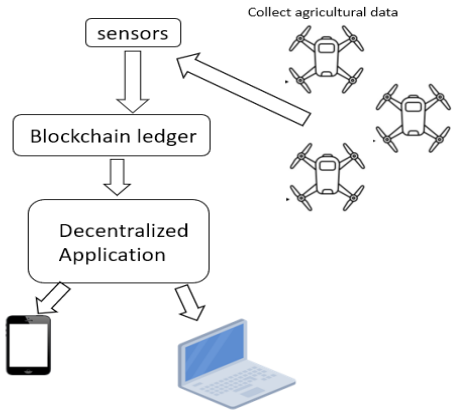
The search process involved using keywords and combinations of keywords related to the above topics. Various search queries were formulated to ensure a comprehensive search for relevant research papers. The search was not limited to a specific time period to include both recent and earlier studies. The initial search results were scanned based on titles and abstracts to determine their relevance to the research objectives. Papers that were considered relevant were further reviewed in detail, and their references were checked for additional sources. This iterative process helped in identifying more papers and ensuring a comprehensive review. In addition to the database search, relevant papers were also identified through manual searches of reference lists of selected papers, as well as through citations within the papers themselves. This helped in identifying additional sources that may not have been captured in the initial database search. The selection criteria for the included papers were based on their relevance to the research objectives, the quality of the research methodology, and the significance of their findings. Only peer-reviewed journal articles, conference papers, and reputable

FIGURE 3 DECENTRALIZED STRUCTURE WITH INTERNET OF DRONE

sources were considered for inclusion in the literature review. By using these rigorous search methods and criteria, a comprehensive collection of research papers was gathered to provide a comprehensive review of the integration of blockchain and IoT technologies in the agriculture sector.

IV. RESULT

In the previous sections, we discussed the overall benefits of the Internet of Things (IoT) and blockchain in the agriculture sector. The



combination of these technologies, as proposed by researchers, has the potential to revolutionize the agricultural industry. In a specific research paper [18], a prototype of a lightweight UAV system was developed, capable of carrying payloads equipped with sensors for collecting flight data such as air speed, ground speed, altitude, throttle, and consumed current. Traditionally, such collected data is stored in centralized systems. However, the use of drones with blockchain technology enhances the security of the stored data. Other studies [13], [14], [15] have also proposed the integration of drones and blockchain to improve data security and enhance precision in IoT applications in agriculture. By storing the collected data from drones and sensors on a blockchain, the information can be shared among network nodes and accessed through decentralized applications (DApps). This enables tracking of agro-foods, visibility into crop health, and updates on climate changes and suitable crop conditions. The combined use of drones, IoT sensors, and blockchain technology establishes a robust infrastructure that spans from data tracking and scanning to data security and precision in the agriculture sector. The utilization of blockchain ensures the immutability and transparency of the collected data, making it highly reliable and resistant to tampering. As further research and development in this field continue, the combined use of drones, IoT, and blockchain is expected to play a transformative role in shaping the future of smart agriculture, reducing human efforts, and driving the sustainable and efficient agricultural practices.

V. CONCLUSION

This paper presents a comprehensive literature review of the research conducted in recent years to explore the application of blockchain and Internet of Things (IoT) technologies in the agriculture sector. The primary focus is on understanding how these technologies can revolutionize agricultural practices and reduce human efforts. The review encompasses various advancements such as the utilization of drones, smart sensors for scanning and mapping crop fields, tracking goods quality using QR codes, and employing blockchain's decentralized approach to store information and maintain transparency between farmers and customers. The integration of these technologies aims to create a secure agriculture management system that enhances efficiency and productivity while addressing the challenges faced by the agricultural industry.

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