AGRICULTURE 4.0: IMPACT AND POTENTIAL CHALLENGES OF BLOCKCHAIN TECHNOLOGY IN AGRICULTURE AND ITS MANAGEMENT

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Abstract: *Information technology can be used to make the best use of things like water, fertilizer, and pesticides in agriculture. Farmers can make better decisions about how to use their resources, reduce waste, and have less of an effect on the environment by using sensor-based monitoring, data analysis, and precision farming techniques. Information technology can make the agricultural supply chain more open, so that consumers and other stakeholders can find out where agricultural products come from and how they are made. The authors looked at articles that had been published in journals before and gave up-to-date information about how blockchain technology could affect agriculture and how it is run. The authors did a descriptive narrative evaluation of how blockchain technology affects agricultural business. They looked at the challenges and benefits of blockchain technology in agriculture. The writing process took four months (between January 2023 and April 2023). We searched databases such as PubMed, Z-library, Publons, Medline, JSTOR, and Google Scholar and obtained original and review articles published in various journals, textbooks, and review papers. Conclusively, one of the primary challenges in agricultural business management is ensuring that farmers, especially those in remote or economically disadvantaged areas, have access to the necessary technology. This includes access to affordable hardware, software, and internet connectivity. Unequal access to technology can result in a digital divide, where some farmers are unable to take advantage of the benefits of information technology in agriculture. This review demonstrated that farmers and agribusinesses need to implement robust data privacy and security measures to protect their information from cyber threats and ensure compliance with relevant data protection regulations.*

Keywords: Agricultural business management (ABM), agricultural safety and regulation (ACSR), agriculture 4.0, blockchain technology, digital transformation, farmers.

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1. Introduction

The agriculture industry has experienced several challenges over the years, such as agri-food safety, traceability, and transparency. Agricultural safety issues, such as agri-foodborne illnesses, have become a global concern, leading to a need for enhanced agri-food traceability and transparency (Rejeb *et al*. 2020). The adoption of blockchain technology in the agriculture industry offers an innovative solution to these challenges. Blockchain technology enables a better scope for the

organization to improve data transparency (Chege *et al*. 2020). Blockchain technology creates the infrastructure that allows the sharing of data among multiple stakeholders, including agri-food producers, distributors, retailers, and consumers. Agricultural traceability is an essential aspect of the agriculture industry, as it ensures agri-food safety, quality, and authenticity. The traditional agricultural traceability system record management is the process that is problematic and also a hectic part in the working area (Köksal and Tekinerdogan, 2019). The adoption of blockchain technology in the agriculture industry offers a comprehensive solution to agricultural traceability challenges.
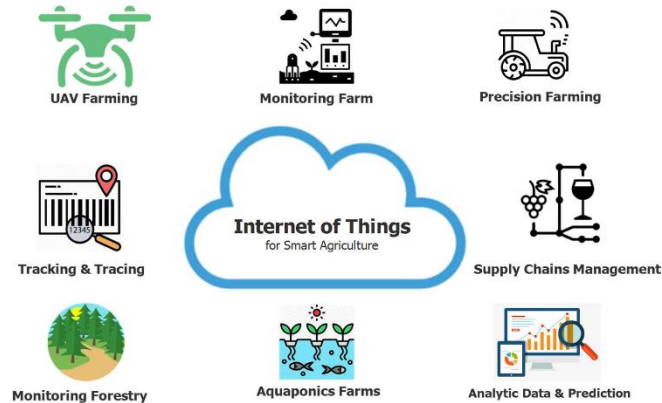

Figure 1: Importance of IoT in Agri business
(Source: Köksal and Tekinerdogan, 2019)

Blockchain technology makes the transparent tracking system agricultural products from farm to fork. This system can be used to store information about each step of the agricultural production process, such as the origin of the product, processing, and transportation (Di Vaio *et al*. 2020). This level of traceability can help identify the source of contaminated agriculture products and prevent the spread of agri-foodborne illnesses. Blockchain technology can also enhance transparency in the agriculture industry by allowing stakeholders to access information about the agriculture supply chain. Transparency is essential to build trust between consumers and agricultural producers (farmers) and improve agri-food safety (Delgado *et al*. 2019). For instance, if there is a agri-foodborne illness outbreak, the blockchain system can help identify the origin of the contaminated agricultural products and prevent the spread of the illness. Blockchain technology can also help enhance supply chain management in the agricultural industry. SCM can be stated as the combination of effective decision making and managing the information in a better way (Zhai *et al*. 2020). Blockchain technology can create a shared platform where all stakeholders is able to access and share data about the supply chain, such as production schedules, inventory, and shipping information. This helps in cutting costs, increasing efficiency, and improving decision-making.

However, the adoption of blockchain technology in the agriculture industry faces several challenges, such as the interoperability of blockchain systems and the cost and complexity of implementing blockchain systems (Smidt and Jokonya, 2022). Currently, there are several blockchain systems in use, and they are not always compatible with each other. This can create challenges when trying to track agricultural products across different supply chains that use different blockchain systems. Blockchain technology also entails substantial investment in hardware, software, and personnel, which can be a significant obstacles to adoption, especially for SMEs in the agriculture industry. Blockchain technology provides the effective solution for managing the complexity in the particular business segment in agriculture (Lezoche *et al*. 2020). The adoption of blockchain technology in the agriculture industry can enhance sustainability of the business working process and evaluation of the performance measures in the agricultural business. However, there is important for understanding and making solution for the issues and present challenges.

The rapid growth of the blockchain market in the agri-food and agriculture industry reflects the potential for this technology to address key challenges in the sector, such as agri-food safety, supply chain management, and transparency. According to critical and concise market research, the global market value of blockchain in the agriculture industry was valued at approximately 140 million U.S.

dollars in 2020 (Statista, 2023). The growth projections for the industry are significant, with experts estimating that the market value of blockchain in the agriculture industry could reach up to "1.5 billion U.S. dollars by 2026 (Statista, 2023). This growth is attributed to the increasing demand for transparency and traceability in the agricultural industry, which has been amplified by several high-profile agri-food safety incidents in recent years.
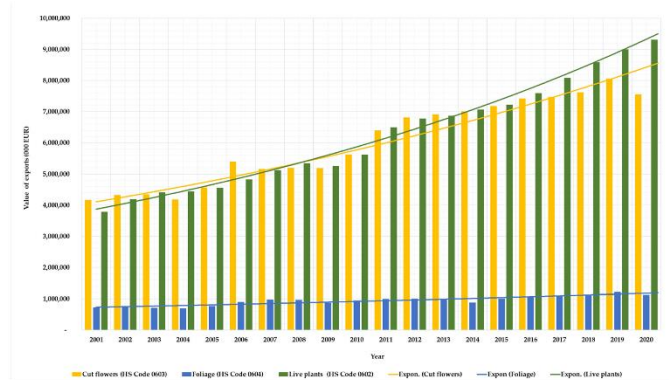
Figure 2: Blockchain technology in the agriculture industry
(Source: Statista, 2023)

Furthermore, the technology is based on the technical implementation that enables a better working scope for the users. Consumers are found highly interested in the source of their agri-food and are willing to pay a premium for products that are sustainably and ethically produced (Lin *et al*. 2020). The technological development in the agriculture industry is running slow and leading in its early stages, and there is considerable potential for innovation and growth in this sector. The technology offers the ability of creating a highly transparent, secure, and efficient agriculture supply chain, which can benefit all stakeholders in the industry, from producers to retailers and consumers (Sharma *et al*. 2020). It has been found that the global market value of blockchain in the agriculture industry is expected to grow significantly over the next few years, reflecting the increasing demand for transparency and traceability in the agriculture supply chain. In the agricultural business area, it is essential to make the entire system proper to improve the sustainability.

Purpose of Study

This review aimed to looks at the impact and potential challenges of blockchain technology in agriculture and its management.

This objective focuses on the concerns:

- To understand the impact of blockchain technology in agriculture and its management
- To derive the potential challenges regarding blockchain technology in agriculture industry
- To know the related solutions for reducing the issues regarding blockchain technology in agriculture industry and management

Significance of the study

The study is focused on discussing the impact and potential challenges of blockchain technology in agriculture and its management. The related issues in blockchain technology will also be discussed in this study. The solutions to the related issues in technology have also been focused on the details that will provide an in-depth understanding. Therefore, the details of the study will be helpful for future researchers to improve their understanding of the research. The flexibility and reliability of the search will also make it easier to complete the studies successfully.

2. Review Parameters

The authors looked at articles that had been published in journals before and gave up-to-date information about how blockchain technology could affect agriculture and how it is run. The authors did a descriptive narrative evaluation of how blockchain technology affects agricultural business. They looked at the challenges and benefits of blockchain technology in agriculture. The writing process took four months (between January 2023 and April 2023). We searched databases such as

PubMed, Z-library, Publons, Medline, JSTOR, and Google Scholar and obtained original and review articles published in various journals, textbooks, and review papers.

Impact of blockchain in agricultural business

Blockchain technology is gaining increasing attention as a game-changing innovation that can revolutionize many industries, including the agricultural business. Using distributed ledger technology, blockchain provides a way with high security and transparency to manage data and transactions, which can help improve supply chain efficiency, increase transparency, and enhance trust between farmers, consumers, and other stakeholders in the agricultural industry (Rijanto, 2021). One of the primary applications of blockchain in the agricultural business is in traceability. Tracking products from farm to table, blockchain helps in ensuring the authenticity and safety of agriculture products. For example, a farmer can record the details of their farming practices, including the use of fertilizers and pesticides, on a blockchain (Kramer *et al*. 2021). This information can then be verified by agri-food processors and retailers, and ultimately by consumers, who can access this information using a "blockchain-based app" or platform. Another way in which blockchain is being used in the agricultural industry is in supply chain management. Providing a way to track products and payments with more security and transparency, blockchain can help reduce fraud, reduce costs, and efficiency enhancement (Oguntegbe *et al*. 2022). Farmers can use blockchain-based platforms to sell their produce directly to consumers or to retailers, excluding the necessity for intermediaries and reducing transaction costs. In addition, blockchain can also enable "peer-to-peer lending", which can help farmers access financing more easily.

Figure 3: Impact of blockchain in agriculture business
(Source: Swain *et al*. 2021)

Smart contracts are another application of blockchain technology in the agricultural business. This can help automate payments and reduce the need for intermediaries (Swain *et al*. 2021). Blockchain technology is potential to transform the agricultural industry by providing a secure and transparent way to manage data and transactions. Improving traceability, supply chain management, and payment systems, blockchain can help increase efficiency, reduce costs, and enhance trust between farmers, consumers, and other stakeholders in the agricultural industry.

Challenges of blockchain technology

The use of blockchain technology has the capacity to significantly transform various industries; however, there are a number of obstacles that need to be overcome before it can be broadly implemented.

Scalability: Blockchain technology is facing a bigger challenge regarding scalability. As more users join a blockchain network, the size of the network grows, and the number of transactions that can be processed per second can become limited. This can lead to slow transaction times and higher transaction fees, making it difficult to use blockchain technology for large-scale applications (Akram *et al*. 2020). Several solutions have been proposed to address this challenge, including sharding and off-chain scaling solutions. Sharding is a technique that involves breaking a blockchain network into

smaller, more manageable parts called shards. Each shard can process transactions independently, increasing the overall throughput of the network. Off-chain scaling solutions that allow for faster and cheaper transactions by moving some transactions off the main blockchain and onto a secondary network.

Figure 4: Challenges of blockchain
(Source: Sanka *et al.* 2021)

Interoperability: Another challenge facing blockchain technology is interoperability. Currently, there are many different blockchain platforms, and they often cannot communicate with each other. This limits the ability to create a seamless, interconnected blockchain ecosystem that can be used across different industries and applications (Sanka *et al.* 2021). Several initiatives are underway to address this challenge, including the progress of cross-chain protocols and interoperability standards. These initiatives aim to create a common framework for different blockchain platforms to interact with each other, allowing for greater collaboration and integration across the blockchain ecosystem.

Regulation: Blockchain technology is considered a new technology, and regulatory frameworks have not yet caught up with its development. This creates uncertainty for businesses and investors, who may be unsure about the legal and regulatory implications of using blockchain technology (Attaran, 2022). Governments and regulatory bodies around the world are working to develop frameworks that will help guide the use of blockchain technology. These frameworks aim to balance innovation and growth with the need to protect consumers and prevent illegal activities.

Security: While blockchain technology is often touted as being highly secured, there are still vulnerabilities that can be exploited by hackers. Another challenge that is faced by blockchain security is the potential for a 51% attack, where a single entity controls more than 51% of the network's computing power. In order to address these security challenges, blockchain developers are working to improve the security of their networks through the use of encryption, multi-factor authentication, and other security measures (Durneva *et al.* 2020). In addition, ongoing R&D are focused on identifying and addressing potential security vulnerabilities in blockchain networks. Blockchain technology holds great promise for transforming many industries, there are several challenges that must be identified priory. Developing solutions to these challenges, we can ensure that blockchain technology reaches its full potential as a secure, scalable, and interoperable platform for innovation and growth.

3. *Benefits of block chain technology in agricultural business*

Improved traceability: One of the most significant benefits of blockchain technology for the agriculture industry is improved traceability. This transparency can help to identify the source of agri-foodborne illnesses and other safety issues quickly, allowing for faster recalls and reducing the risk of widespread outbreaks.

Blockchain technology is able to increase the effectiveness of the agricultural supply chain by reducing the time and cost associated with paperwork and record-keeping. Automating many of these processes, blockchain can help to streamline the supply chain and mitigate the risk of errors or delays (Chen *et al.* 2021). Blockchain technology can also help to increase transparency in the agricultural supply chain. This can help to build trust among consumers and provide them with information about the origin of their agricultural elements, how it was produced, and how it was transported. Improving

traceability and increasing transparency, blockchain technology can help to improve agricultural safety. This can help to reduce the risk of agri-foodborne illness and improve the overall quality of agriculture products (Kaur *et al*. 2022). Blockchain technology can also help to reduce agri-food waste by allowing for better inventory management and reducing the risk of spoilage or expiration. Blockchain technology can help in improving supply chain management through the real-time visibility in terms of the movement of goods and identifying potential bottlenecks or issues before they become major problems. Blockchain technology holds great promise for the agriculture industry, offering benefits in terms of traceability, efficiency, transparency, agri-food safety, reduced waste, and better supply chain management (Li *et al*. 2021).

Theoretical overview

The "Technology Acceptance Model" (TAM) is a way to understand and predict how people will react to new technologies. TAM has been used with many different technologies, including blockchain, and it can help you understand how blockchain development is adopted. Kemp et al. (2019) say that the model predicts that people will use a new technology based on how useful they think it is and how easy they think it is to use. Perceived usefulness is how much users think a technology will help them do their jobs better or be more productive. Perceived ease of use is how much users think a technology is easy to use and understand. In order to facilitate blockchain development, perceived usefulness can refer to the potential benefits that blockchain can offer in terms of security, transparency, and efficiency. For example, blockchain technology can help to improve supply chain management by focusing on deduction of fraudulent cases, real-time visibility into the movement of goods, and improving the overall quality of products in agriculture business management.
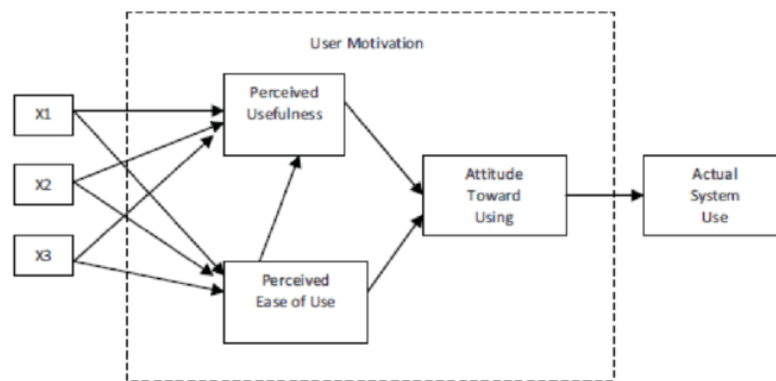

Figure 5: Technology acceptance model
(Source: Kemp *et al*. 2019)

On the other hand, the use can refer to the user-friendliness of blockchain development tools and platforms. In the case of blockchain development, the tools are difficult to use and require a high degree of technical expertise, which may deter some users from adopting the technology. Other factors that can inspire the acceptance of blockchain technology include social influence, such as the influence of peers or industry leaders, and trust in the technology and its providers (Al-Nuaimi and Al-Emran, 2021). The "technology acceptance model" can be a useful framework for understanding and predicting the adoption of blockchain development. Focusing on the perceived usefulness and perceived ease of use of blockchain technology, developers can design tools and platforms that are more likely to be adopted by users, ultimately leading to wider adoption and increased innovation in the blockchain space.

4. Methodology

Methodological direction is one of the most crucial parts of the research study. This enables a better scope for achieving the success level in the research study. Defining the research objective or research question that the study aims to answer using a positivist research philosophy. In this segment, the investigation on the influence of blockchain technology on agriculture management safety practices in the agricultural supply chain is presented (Abu-Alhaija, 2019). This also helps the researchers make a proper decision on the working process of the research. A descriptive research

design is useful for providing a comprehensive and detailed description of a research topic or phenomenon. It is particularly suitable when the research objective is to explore and describe the current state of a phenomenon or to generate assumptions for further research. However, it has limitations such as potential biases in data collection, a lack of control over variables, and a limited ability to establish causality (Doyle, 2020). Therefore, researchers should be cautious in interpreting the findings and should consider the strengths and limitations of a descriptive research design in the context of their research objective and research question. In this study, a descriptive research design has been used to make the entire process smoother in the research area.

The deductive research method is useful for testing theories or hypotheses that have already been made and providing evidence for or against them. It works best when the goal of the research is to prove or disprove a specific theory or hypothesis and when the design of the research is clear and structured (Pearse, 2019). But it has some problems, like the possibility of bias in data collection, a limited ability to search new research publications, and a reliance on theories that have already been tested. In this study, this method was used to put the focus on how decisions were made. In this particular research study, secondary data has been collected to perform the analysis. Different journals and the design of the models have also helped the researcher improve the decision-making process in selecting this particular research. Thematic data analysis is a qualitative research method used for examining and interpreting patterns, themes, or meanings (Braun and Clarke, 2019). This method involves organizing and grouping data in a structured manner, based on recurring patterns or themes that are identified within the data.

When it comes to blockchain technology in the agriculture business, thematic data analysis can be used to learn more about the qualitative aspects of the phenomenon. In this study, secondary thematic analysis was used to improve both the way decisions were made and how performance measures were evaluated. Hancock et al. (2020). The ethical side of the project is another crucial component that the researchers must manage. Researchers should make sure they have the right permissions and legal access to the secondary data they are using. This means checking the source of the data, knowing the rules for using the data, and following any copyright or intellectual property laws that apply by citing the necessary authors where it is necessary.

5. Discussions

Theme 1: Developing industry 4.0 in manufacturing sustainability in agricultural business

Industry 4.0, well-known as the Fourth Industrial Revolution, is the convergence of digital technologies, automation, and data exchange in manufacturing processes. It has the potential to revolutionize the agricultural business by optimizing operations, improving sustainability, and enhancing overall performance. In this context, developing Industry 4.0 in manufacturing sustainability can have significant benefits for the agricultural business (Hancock *et al.* 2020). One of the key areas where Industry 4.0 has the ability contribute to sustainability in the agricultural business is through improved resource efficiency. Advanced technologies such as Internet of Things (IoT), artificial intelligence (AI), and big data analytics can enable real-time monitoring and optimization of energy and water consumption, waste management, and other critical resources. This can result in reduced resource waste, increased operational efficiency, and minimized environmental impact, leading to improved sustainability in the agri-food manufacturing process.

Another aspect of Industry 4.0 that can promote sustainability in the agricultural business is the integration of smart sensors and automation in production processes. Smart sensors can collect data on various parameters such as temperature, humidity, and quality of raw materials, and transmit this data to the production systems for analysis and decision-making (Keskinbora, 2019). Automation can then be used to optimize production processes based on the data collected, resulting in reduced errors, improved quality control, and minimized waste.

Furthermore, Industry 4.0 can enable better supply chain management in the agriculture business, which can contribute to sustainability. Along with the help of IoT and blockchain technology, supply chain processes can be streamlined, and traceability and transparency can be improved. This can help in identifying and addressing issues such as agricultural fraud, agricultural safety, and sustainability certifications, ensuring that the agricultural products are sourced responsibly and

produced sustainably (Hall and Studdert, 2021). However, developing Industry 4.0 in manufacturing sustainability in the agricultural business also presents challenges. These challenges may include high initial investment costs, technological complexities, cybersecurity risks, and workforce skill requirements. Additionally, ethical considerations such as data privacy, security, and the impact on the workforce and society need to be carefully addressed in the implementation of Industry 4.0.

Theme 2: Development of IoT in agricultural business for better working procedure

The IoT is a revolutionary technology that is transforming various industries, including the agricultural business. The integration of IoT in the agriculture industry has the potential to significantly improve the working procedures and operations, leading to enhanced efficiency, safety, and sustainability. IoT can bring about positive changes in the agriculture business in the supply chain management. IoT devices, such as sensors and RFID tags, can be used to track and check various concerns of the supply chain that includes temperature, humidity, location, and quality of agriculture products (Obaideen *et al.* 2022). This real-time data can be transmitted to a central system, allowing for better visibility and traceability of agricultural products throughout the entire supply chain. This helps in identifying and addressing potential issues such as spoilage, contamination, and delays, ensuring that the agricultural products are transported and stored in optimal conditions, thus minimizing waste and improving agricultural safety. IoT can also be used to optimize inventory management in the agriculture business. With the help of smart sensors, inventory levels can be monitored in real-time, allowing for timely reordering and reducing the risk of stockouts or overstocking (Adeleke *et al.* 2023). This ensures that agricultural products are always available in the right quantities, minimizing agricultural waste and optimizing inventory costs.

Figure 6: IoT ad impact in business
(Source: Adeleke *et al.* 2023)

IoT can improve the monitoring and control of production processes in the agriculture business. Sensors are used to collect data on various parameters such as temperature, humidity, and equipment performance, enabling real-time monitoring and predictive maintenance. This helps in identifying potential issues or inefficiencies in the production process, allowing for timely adjustments and optimizations, leading to improved productivity and reduced downtime (Khan *et al.* 2020). In addition to supply chain and production management, IoT can also enhance agri-food safety and traceability. Considering the power of blockchain technology, IoT data can be securely recorded and stored, providing a transparent and immutable record of the entire journey of a agriculture product, from farm to table. This enables better traceability, accountability, and trust in the agriculture supply chain, ensuring that agriculture products are safer and highly efficient.

Theme 3: Sustainable business models using technical development in agriculture business

Sustainable business models in the agriculture industry are increasingly incorporating technical development to address key challenges and create innovative solutions. These models aim to balance economic growth with environmental and social responsibility, ensuring that the agriculture industry operates in a manner that is environmentally friendly, socially equitable, and economically viable in the long term (Belaud *et al.* 2019). The factor driving sustainable business models in the agriculture

industry is in the area of agriculture production and agriculture. Emerging technologies such as precision agriculture, hydroponics, and vertical farming are being used to optimize crop yields, reduce water and resource consumption, minimize waste, and decrease the use of harmful chemicals in agriculture production. These technologies enable more efficient and sustainable farming practices, allowing for higher yields and lower environmental impact, while also reducing the need for harmful pesticides and fertilizers. Technical development is driving sustainable business models in the agriculture industry and is in the area of supply chain management (Kayikci *et al*. 2022). Technologies such as blockchain, IoT (Internet of Things), and data analytics are being used to improve traceability, transparency, and accountability in the agriculture bsupply chain. This allows consumers and businesses to track the origin, quality, and sustainability of agriculture products, ensuring that they are sourced responsibly and meet ethical and environmental standards.

Theme 4: Blockchain for IoT development in agriculture business to improve the future
Blockchain technology combined with the IoT is revolutionizing the agriculture industry and has the potential to significantly improve the future of agriculture businesses. The integration of blockchain and IoT can enhance transparency, traceability, and efficiency in the agriculture supply chain, leading to increased consumer trust, reduced agricultural fraud, and improved sustainability. One of the key benefits of using blockchain for IoT development in the agriculture business is improved traceability (Zhao *et al*. 2019). Leveraging blockchain's decentralized and immutable nature, agriculture products can be uniquely identified and tracked at every stage of the supply chain, from farm to fork. IoT devices, such as sensors and smart labels, can collect data on various parameters, such as temperature, humidity, and location, and record them on the blockchain. This creates a transparent and tamper-proof record of a agriculture product's journey, allowing consumers and businesses to trace its origin, processing, and transportation, ensuring its quality and safety.
Blockchain for IoT development in the agriculture business also helps in reducing agricultural fraud. Agricultural fraud, such as counterfeit products or mislabeling, is a significant challenge in the agriculture industry. Blockchain can prevent agricultural fraud by capturing a secured and transparent system that verifies the authenticity and integrity of agriculture products. IoT devices can collect data on several parameters, such as weight, composition, and DNA markers, and record them on the blockchain. This data can then be used to authenticate the agriculture products and detect any discrepancies or anomalies, reducing the risk of agricultural fraud (Ray *et al*. 2019). The use of blockchain for IoT development in the agriculture business can promote sustainability. With increasing consumer demand for sustainable and ethically sourced agri-food, blockchain can enable transparent and reliable tracking of sustainability certifications, such as organic, fair trade, or non-GMO. This can help consumers make informed choices and incentivize agriculture businesses to adopt more sustainable practices in their supply chains, leading to improved sustainability performance across the industry.

6. Summary

Information technology can be used to make the best use of things like water, fertilizer, and pesticides in agriculture. Farmers can make better decisions about how to use their resources, reduce waste, and have less of an effect on the environment by using sensor-based monitoring, data analysis, and precision farming techniques. Information technology can make the agricultural supply chain more open, so that consumers and other stakeholders can find out where agricultural products come from and how they are made. Conclusively, one of the primary challenges in agricultural business management is ensuring that farmers, especially those in remote or economically disadvantaged areas, have access to the necessary technology. This includes access to affordable hardware, software, and internet connectivity. Unequal access to technology can result in a digital divide, where some farmers are unable to take advantage of the benefits of information technology in agriculture. This review demonstrated that farmers and agribusinesses need to implement robust data privacy and security measures to protect their information from cyber threats and ensure compliance with relevant data protection regulations.

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