

Applications and Challenges of Blockchain Technology in Agriculture Sector: A Review

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Abstract

Technology plays an important role in the growth of the country. New technologies are helping people in doing the tasks more effectively by saving time, money and effort. Information, Communication and technology helped to push the stagnant growth of Indian industries. In agriculture, dissemination of information has helped people to acquire knowledge of farming activities, sharing needs, access to the market through TV and radio. As technology is evolving, Artificial Intelligence, Machine learning, Deep learning have paved the way in the agriculture sector. Simultaneously, the Government of India took up the initiative of establishing and supporting 10,000 Farmer Producer Organizations to strengthen the farming community and the Indian agriculture sector. In making the initiative successful, apt deployment and use of technology will play a critical role. In this article, the authors have discussed, what blockchain technology is, its applications and challenges in the agriculture sector.

Keywords: ICT, Blockchain technology, traceability, FPO, Agriculture

Introduction

Agriculture is the prime sector in India. Agriculture is a main source of livelihood for the majority of the population and 54.6 per cent of the total workforce is engaged in the agriculture and allied sector (Census 2011). According to the Annual Report 2020-21 of the Department of Agriculture, Cooperation & Farmers' Welfare, agriculture and allied sector activities

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account for 17.8 per cent of the country's Gross Value Added (GVA) for the year 2019-20. The farming community have gradually shifted from traditional farming practices inherited from generations to scientific practices disseminated by research institutions and universities. Technology is playing a significant role by reaching larger masses from the wider geography of India.

Information and Communication Technologies (ICT), and emerging technologies and applications like the Internet of Things (IoT), etc are helping to disseminate information and knowledge to the farmers.

Today, technology has gone a step ahead, where Artificial Intelligence (AI) is playing a vital role in bringing more advancement, automation, and sophistication in agriculture activities. Machine learning, deep learning, blockchain are among the modern technologies which are being used in agriculture. Among them, Blockchain technology, especially, got more attention because of its nature of applications and scope in securing and safeguarding the food and agriculture systems. It has the potential to address the challenges of the agricultural stakeholders and Farmer Producer Organizations (FPO) are one of them.

To strengthen the agricultural sector of the country by recognizing its importance and supporting the farmers, the Government of India has come up with Farmer Producer Organisations (FPOs). During 2011-12, the Government of India launched a pilot programme for promoting FPOs. The pilot programme involved the mobilisation of approximately 2.50 lakh farmers into 250 FPOs (each with an average membership of 1000 farmers) across the country. The pilot programme showed encouraging results and more than three lakh farmers have been mobilised. Presently, around five thousand FPOs (including FPCs) are in existence in the country. More recently, in the Union budget of 2019-20, the Government of India has declared its intention to promote 10,000 FPOs in the next 5 years to ensure economies of scale for farmers in the country (Strategy Paper for promotion of 10,000 Farmer Producer Organisations (FPOs), 2019 by Small Farmers' Agribusiness Consortium (SFAC)).

Technological Transformation: Perspectives from India

Information, Communication and Technologies are the three foundation pillars of the new advancement happening in all sectors and agriculture is no exception to that. The information from the experts, scientists in the field of agriculture is disseminated to the farmers and other agri enthusiasts through radio, television and social media. The challenges faced by the farmers on the ground are shared with these experts and they provide the appropriate information. In doing so, apt tools and technology are used, and information is exchanged.

ICT has made farming more convenient and profitable, it helped to retain the farmers in farming activities, moreover, it is attracting the rural youth towards agriculture. There was a need for timely, accurate, pertinent information services and ICT played a key role to fulfil the lacuna (Panda, Paswan, & Singh, 2018). The Village Resource Centre functioned as the main hub for disseminating information and identifying the needs of the farmers. Previously, VSAT and radio were used as a medium for communication between farmers and experts. This system helped farmers to get meteorological information and become aware of the market conditions (Swaminathan & Swaminathan, 2018).

ICT further led to the development of Mobile Apps. The farming apps such as Kisan Suvidha, IFFCO Kisan, RML Farmer, Pusa Krishi, AgriApp, Kheti-Badi, Crop Insurance app are helping farmers to get appropriate knowledge of inputs, crop production, crop protection, marketing, processing, fertilizers, pesticides, weather conditions etc. mKisan portal, Farmers portal, National Agriculture Market Portal (e-NAM), Agricoop, APEDA, AQUA, AGRISNET, ITC-e-choupal are farmer friendly portals which are helping farmers to gain farming knowledge and learn about new technologies (Panda, Paswan, & Singh, 2018). Appropriate information helps the farmer to use it in regular farm activities and it leads to improved income for the farmer. Information regarding fair market prices creates transparency in the market. The marketer is getting valid data of demand and supply of the

products in the market and farmers are connecting to new Government schemes which again help the farmers to get financial as well as technical support.

Artificial Intelligence (AI) has evolved as the next step of ICT where machines are made intelligent with more experiences in the form of data. Huge data is generated during agricultural operations and activities, and it is made accessible for analysis and interpretation. Machine Learning (ML) a part of AI, could be programmed with a set of agricultural data to perform various farm operations without human interference, which would enable in solving various complex tasks (Kumar & Sahu, 2021).

With technological use, more data are generated and processed every minute. People have started relying on technology for taking decisions. Hence preventing data manipulation has become important. Herein, Blockchain technology plays a critical role. Blockchain technology is attracting significant attention in various agricultural applications (Fang & Wang, 2020) as this technology has a wide scope in the agriculture sector and can solve pertinent issues like traceability, food safety, supply chain, monitoring and management.

Introduction to Blockchain

Blockchain is a digital ledger of transactions that cannot be manipulated like an excel sheet or pen and paper records. Each block contains a record of every transaction. Once the block is filled, a new block is created. All these blocks get linked with each other like a chain, hence, it is called blockchain.

The decentralised database in the blocks managed by multiple participants is known as Distributed Ledger Technology (DLT). Blockchain is a type of DLT in which transactions are recorded with an immutable cryptographic signature (www.euromoney.com) hence, the data is more secure than other ledgers.

Blockchain is an emerging digital technology that allows widespread financial transactions between underutilized groups, without the need for intermediaries such as banks (Mehta, Sharma, & Patel, 2021). By understanding the working methodology blockchain can be used not only in the financial industry but also in agriculture, service, aviation etc.

Types of Blockchain

Blockchain has different structures based on its types. The types of blockchain are based on the permission for users to enter the blockchain. These can be characterized as permissionless, permissioned, or both. Permissionless blockchains are the ones which allow all the users to join the blockchain. Permissioned blockchain restricts the user's access to join it (Wegrzyn & Wang, 2021).

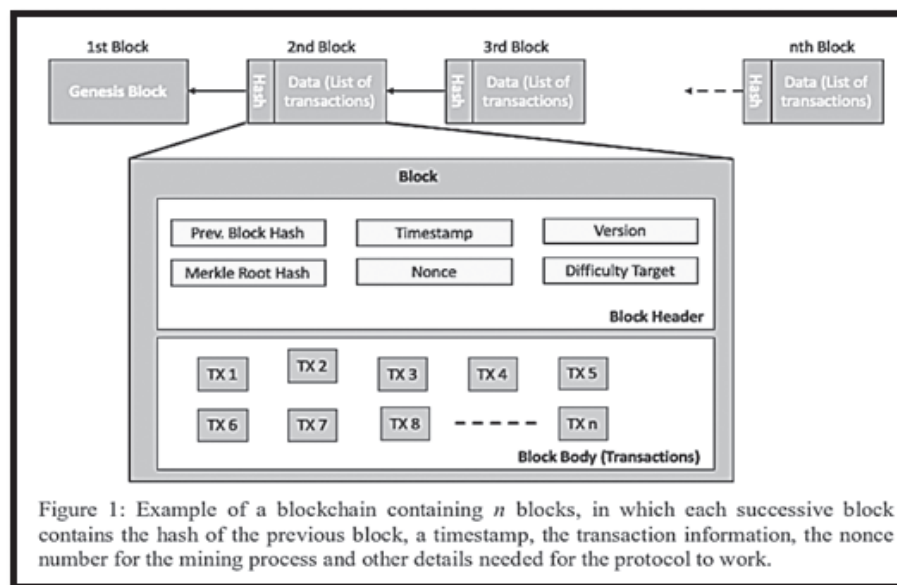
On the basis of types of blockchain, there are certain structures of blockchain, i.e. Public, Private, and Consortium. Public blockchains allow all the people to join the blockchain, access it, and create a new block. On the other hand, in Private Blockchains, the control is with only one organization. In Consortium blockchain the rights to allow and join the blockchain is given only to a selected set of nodes (Zheng, Xie, Dai, Chen, & Wang, 2017).

Flow activities in Blockchain

In a blockchain, each block contains the hash of the previous block which is used to link it with the next block, at each transaction hash value changes. After each transaction, data get stored in a block and after saturation of the first block, the next block is created. A class of participants on this network, called miners, are responsible for detecting transaction requests from users, aggregating them, validating them, and adding them to the blockchain as new blocks (Goundar, 2020).

Being a distributed ledger technology, blockchains records cannot be changed, manipulated, or deleted. It creates more transparency and security among the users. Customers can use their computers or mobile phones to

retrieve and verify all transaction data (Mehta, Sharma, & Patel, 2021). For example, if a buyer wants to purchase meat from the market, by using a smartphone scan he can get the information about the location and conditions in which that animal has been reared, slaughterhouse location, equipment used for slaughtering, packing information etc.



Source: Adapted from Kamilaris, Fonts, & Prenafeta-Boldu', *The Rise of Blockchain Technology in Agriculture and Food Supply Chains*, 2019.

Application of Blockchain Technology in Agriculture

The agriculture sector is witnessing a revival with the introduction of new startups and their technologies. Digital India initiative led to the digitization of several agricultural activities which has further led to the generation of enormous data. Micro or macro level decision making has become dependent on the data. Thus, safeguarding the data is of utmost importance. Blockchain technology is adding the value to the same. There are numerous applications for the technology which are discussed below.

- **Traceability:** According to the International Organization for Standardization (ISO), Traceability is the "ability to trace the history, application, or location of that which is under consideration"

(Chhikara, et al., 2018). Implementation of effective traceability systems improves the ability to implement verifiable safety and quality compliance programs (Traceability in Food and Agricultural Products by International Trade Centre, 2015). Traceability can be used in various activities in agriculture i.e., from getting Agri inputs from input dealers up to supplying the final produce to the end consumer.

In January 2018, the World Wildlife Foundation (WWF) announced the Blockchain Supply Chain Traceability Project (WWF 2018), to eliminate illegal tuna fishing by means of blockchain. Through the project, fishermen can register their catch on the blockchain through RFID e-tagging and scanning fish (Kamilaris, Fonts, & Prenafeta-Boldo', 2019) (Balfego' Group 2017).

- **Transparency:** As businesses are moving towards digitalization, transparency plays a key role to grow the business. Transparency helps to provide information to all the stakeholders in the business and decision making to take the right action. Transparency is associated with positive connotations such as trust and accountability (Hosseini, Shahri, Phalp, & Ali, 2017). Transparency helps external stakeholders to monitor the internal activities of any business (Douglas & Meijer, 2016).

My Crop is an Ahmedabad (India) based Agritech Startup currently testing blockchain in the seed supply chain to track its entire supply movement from seed aggregators, distributors, retailers to farmers. The aim of using blockchain technology in the business is to bring transparency, authenticity and to restrict spurious and low-quality seeds from entering the market (Inc 42).

National Agriculture Market (eNAM) is a pan-India electronic trading portal which networks the existing APMC mandis to create a unified national market for agricultural commodities www.enam.gov. The trading is to be done through a digital platform as prescribed to ensure

transparency in the transactions and provide a fair price to the farmers. Goundar, 2020 conducted a study in three APMCs of Uttar Pradesh to analyse the ground-level practices taking place in these APMCs and the level of adoption of e-NAM. It was found that there is a considerable variation in the arrival and bidding prices obtained from the APMCs when compared with the data available on the agriculture market information system (Agmarknet). The study proposes a blockchain-based infrastructure to facilitate a more transparent, autonomous system to empower the information system and efficient application of government rules and regulations pertaining to agricultural transactions in the APMCs through the utilization of smart contracts.

- **Agri and Food Supply chain:** A supply chain is the set of entities that are involved in the design of new products and services, procuring raw materials, transforming them into semi-finished and finished products and delivering them to the end customers (Swaminathan 2001). Supply chain management is an end-to-end process consisting of different activities from product design, procurement, planning and forecasting, production, distribution, fulfilment, and after-sales support (Xiaoyuan Lu & Swaminathan, 2015).

Blockchain in supply chain management is expected to grow at an annual growth rate of 87 per cent and increase from \$45 million in 2018 to \$3,314.6 million by 2023. As a successful example, in December 2016, the company AgriDigital executed the world's first settlement of the sale of 23.46 tons of grain on a blockchain (ICT4Ag 2017). Since then, over 1,300 users and more than 1.6 million tons of grain has been transacted over the cloud-based system, involving \$360 million in grower payments. The success of AgriDigital served as an inspiration for the potential use of this technology in the agricultural supply chain (Chang, Iakovou, & Shi, 2019).

- **Food safety:** Foodborne illnesses are usually infectious or toxic in

nature and caused by bacteria, viruses, parasites or chemical substances entering the body through contaminated food or water. Blockchain could provide an efficient solution in the urgent need for improved traceability of food regarding its safety and transparency (Kamilaris, Fonts, & Prenafeta-Boldu', 2019).

Food companies are using blockchain technology in their business to build trust, transparency among the customers by providing support for all the processes. In the demonstrated pilot, examples of chicken assigned in San Francisco were put together with QR codes that link to their meat story. Consumers will have the opportunity to check the QR code on the Grass Roots item to see where the meat originated and how the organisms grew (Mehta, Sharma, & Patel, 2021).

- **Food Integrity:** Food Integrity is "the state of being whole, entire, or undiminished or in perfect condition", providing assurance to consumers and other stakeholders about the safety, authenticity and quality (secure.fera.defra.gov.uk).

Food integrity is about the reliable exchange of food in the supply chain. Each actor should deliver complete details about the origin of the goods. Downstream beer (Ireland Craft Beers 2017) is the first company in the beer sector to use blockchain technology, revealing everything one wants to know about beer, i.e. its ingredients and brewing methods. (Kamilaris, Fonts, & Prenafeta-Boldu', 2019).

- **Cryptocurrency:** Cryptocurrency is a digital currency also called digital money. The number of Cryptocurrencies present today includes Bitcoin, Ethereum, Ripple, Litecoin and IOTA. The main advantage of Cryptocurrency over the traditional one is it does not require a central authority for a transaction. In the case of cash transactions, the bank is playing the role of a central authority which is not required in cryptocurrency. Cryptocurrency is more secure and transparent.

Bitcoin, the first digital money, was introduced in 2009 by Satoshi Nakamoto. The Bitcoin Blockchain is a data file that carries the records of all past Bitcoin transactions, including the creation of new Bitcoin units (Berentsen & Schär, 2018). Cryptocurrencies are scarce commodities and currency units are case limited by mathematical algorithms. After every digital currency unit is issued, there is no way to generate additional currency units from it (e.g. Bitcoin is limited to 21 million units) (Goundar, 2020).

- **E-commerce platforms:** Nowadays the use of E-commerce platforms for buying and selling goods and services has become more common. Social media platforms are playing a vital role in the growth of E-commerce. With the advent of Cryptocurrencies, the possibilities of e-commerce have reached new heights for all web users who see potential in this technology (Goundar, 2020). The use of Blockchain in E-commerce will help to reduce the cost of the transaction, boost security, supply chain and inventory management, verified view or getting a feedback from customers (Faulkner, 2021). AORA is a blockchain assisted global buying platform for cross-border e-commerce and end-to-end crypto shopping. AORA allows customers to purchase items from online marketplaces in the U.S. and China, using cryptocurrencies as tender <https://www.aora.com/>.
- **Smart Contracts-** Contract is 'an agreement enforceable by law'. It is an agreement between two or more persons (individuals, businesses, organizations, or government agencies) to do, or to refrain from doing, a particular thing in exchange for something of value (Jajodia, 2012). In agriculture, different contracts are signed at the time of buying and selling of Agri commodities. In the recent past, farmers have been inclined towards contract farming which in turn benefits the companies as well. After getting into the contracts farmers are also facing many conflicts and disputes due to complications in terms of paperwork. A Smart contract is an application of blockchain which could help to

solve disputes and conflicts among the farmers in a fairer way for everyone (Chinaka, 2016; AgriDigital, 2017). The US-based startup 'Second State' provides developer tools for decentralized apps and a search engine for smart contracts, as well as blockchain as a cloud service. It develops virtual machines for blockchain smart contracts in leading public blockchains including Ethereum, Polkadot, and CyberMiles (www.startups-insights.com).

- **Labour Problems:** Agriculture is a labour-intensive sector where seasonal labour are hired for the work. These labourers become unemployed without any intimation. Blockchain-based contracts can help in protecting workers with temporary agreements and employment relationships in the agricultural sector to mitigate the exploitation of labour in agriculture (Pinna & Ibba, 2018). It is easier for the authorities to control fairness in payments and taxation due to blockchain. Coca-Cola has attempted to employ blockchain to sniff out forced labour in the sugarcane sector (Chavez-Dreyfuss, 2018; Kamilaris, Fonts, & Prenafeta-Boldu', 2019).
- **Supervision and quality measurement:** In order to strengthen the effectiveness of supervision and management in the food supply chain, blockchain technology can be harnessed as a credit evaluation system. In addition to that, it can also be used to improve the monitoring of international agreements relevant to agriculture (Tripoli & Schmidhuber, 2018)(Kamilaris, Fonts, & Prenafeta-Boldu', 2019). In quality assurance, failures such as delays in final destinations, poor monitoring are avoided, and the quality of produce is assured through the food chain (Brooker, Bakker-Arkema, & Hall, 1992) (Kamilaris, Fonts, & Prenafeta-Boldu', 2019).
- **Certification/Documentation:** Various documents are required to avail funds or to take benefits of Government Schemes in India. If the farmers want to apply for the scheme, the flow of documents needs to be

monitored. Many farmers miss their important documents in this process. Here, Blockchain technology is helpful to monitor the process flow.

Blockchain can solve this existing problem of verifying the validity of digital assets such as a picture of the birth certificate, a pdf document stating the will or a signed legal document specifying a business deal very efficiently and at a very low implementation cost. Blockchain is used for the very specific task of storing digital signatures of assets that prove their validity.

Due to the characteristics of the Blockchain (permanent decentralised ledger of information), these digital signatures can be accessed by anyone. Hence, anyone with access to the Blockchain can now verify the authenticity of a digital asset without having to rely on trusted intermediaries.

The Blockchain is not the solution to the Signed Digital Asset problem. Rather it plays a small but important part in this proposed solution.

- **Land registration:** Land registration, cadastre and land governance play an important role in society, as long as they function legally and transparently and meet the goals set by society. Land registries/land registration is where documents, manifesting legal rights from a property transaction, are recorded. Cadastre is the process of mapping those rights and subsequent storage of the mapping data. A number of disputes are arising regarding ownership rights when the land has been sold several times. Blockchain is effective here to maintain a record and data of the whole history of the flow of the processes.

In India, currently, the ownership of a property is proved through presumptive land titling (RoR)-chain of documents that provide evidence of the transfer of the title from person to person over the years all the way to the current owners. Registration is only recognized

as an agreement between two parties for the transfer of property. An important constraint is that any one of these intermediate transactions is liable to be challenged as the office of the sub-registrar (SRO) is only undertaking deed registration under the Central Registration Act 1908 and does not verify the ownership of the land. Property fraud is also rampant in many forms in our country.

The farmer has to spend time and money to collect all the documents such as RoR, mutation extract, crop certificate etc. that are necessary for securing loan, subsidy and any other benefit from the Government.

Challenges while using blockchain technology

- **Regulation:** Policy development and regulation in relation to blockchain practices is both a necessity and an important barrier for its wider adoption (Zhao, et al., 2019; Kamilaris, Fonts, & Prenafeta-Boldu', 2019). Without a systematic regulation structure, it is difficult to adopt this technology. Blockchain applications in cryptocurrency are banned in some countries and some countries are trying to fix strict regulations of it.
- **Digital Gap between Developed and Developing Countries:** Since blockchain technologies require a high degree of computing equipment and expertise (i.e. in some blockchain systems, such as permissionless ones) (Zhao, et al., 2019)(Kamilaris, Fonts, & Prenafeta-Boldu', 2019) it is difficult to adopt this type of technology for developing countries. Due to this, it may lead to a Digital Gap between Developed and Developing Countries.
- **Privacy issues:** Although blockchain offers advanced security, there are high risks related to loss of funds, just because the account owner might have accidentally lost the private keys needed to access and manage the account (Kamilaris, Fonts, & Prenafeta-Boldu', 2019).

- **Delay issue:** Due to the complex, distributed and encrypted nature blockchain technologies have low transaction speed. In bitcoin Blockchain transactions are carried out in one second, which is very low compared to VISA and PayPal. The time required to confirm the transaction is around 10 minutes and the size of each block is around 1 MB (Kohad, Kumar, & Ambhaikar, 2020). Users may face problems in making financial transactions due to the delay issue in the blockchain.
- **Storage capacity:** In a blockchain, when one block gets saturated with data, the next block gets created; as the chain of blocks grows it requires additional storage capacity and this big chain reflects a negative impact on performance and increases synchronization time for new users (Dhaliwal & Malik, 2021).
- **Blockchain technologies require high consumption of Hardware and Energy:** Just like the mining of special metal requires high cost due to its demand in the market comparably due to Proof-of-Work mechanism, energy cost associated with mining of blocks is also high. According to a study by Oak Ridge Institute in Cincinnati, it has been found that the energy cost of mining bitcoins is nearly 7 megajoules of energy which is equivalent to mining platinum (Hern, 2018). Like energy, blockchain requires a high use of hardware.
- **High Cost:** Due to the requirement of high technology, higher energy and hardware usage, special equipment and expertise to conduct the operations, the cost of adopting blockchain technology is also high. It is difficult for small and medium enterprises to adopt this technology.

Conclusion

Technology is changing the way of thinking and perspective of everyone. People are becoming more optimistic to acquire knowledge and to adopt innovative technologies. Blockchain has bought the trust factor in the usage

of the technology. Blockchain technology is applicable in many industries and agriculture is one of them. It can be used to resolve many challenges in the agriculture and allied sector.

During the formation of Farmer Producer Organizations and implementation of their operations, viz. procurement of input, managing the inventory, recording transaction details, financial statements, documents of membership and land records, logistic and supply chain management, etc. blockchain will play an important role. Moreover, crop or animal insurance, advisory services, stakeholder management and strategic planning will also be strengthened by the use of technology. A few Indian Startups, viz., Samudra Network, Kultivate, TRST01, TraceX are continuously working on blockchain technology and helping farmers and farmer producer organizations to effectively improve their practices and thereby lead to improved productivity.

The usage of blockchain technology in the Indian agriculture sector is still in a nascent stage. More sensitization and adaptation is required. Especially, the adaptation of this technology by farmer producer organizations, as an integral component of the ecosystem, will write a new chapter in the Indian agriculture sector.

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